DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-161203

INSTALLATION, OPERATION, AND MAINTENANCE FOR THE PYRAMIDAL OPTICS SOLAR SYSTEM INSTALLED AT YACHT COVE, COLUMBIA, SOUTH CAROLINA

Prepared by

Wormser Scientific Corporation
88 Foxwood Road
Stanford, CT 06903

Under Contract NAS8-32250 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

U.S. Department of Energy

Solar Energy

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.
DOE/NASA CR-

2. GOVERNMENT ACCESSION NO.

3. RECIPIENT'S CATALOG NO.

4. TITLE AND SUBTITLE
Installation, Operation, and Maintenance for the Pyramidal Optics Solar System Installed at Yacht Cover, Columbia, SC

5. REPORT DATE
September 1980

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

8. PERFORMING ORGANIZATION REPORT #

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Wormser Scientific Corporation
88 Foxwood Road
Stanford, CT 06903

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.
NAS8-32250

13. TYPE OF REPORT & PERIOD COVERED
Contractor Report

12. SPONSORING AGENCY NAME AND ADDRESS
National Aeronautics and Space Administration
Washington D.C. 20546

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
This work was done under the technical management of Mr. Mitchell Cash, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

This report contains information concerning the installation, operation, and maintenance of the pyramidal Solar System for space heating and domestic hot water. Included are such items as principles of operation, sequence of installation, and procedures for the operation and maintenance of each subsystem making up the solar system. Also included are trouble-shooting charts and maintenance schedules.

The final design and results are contained in documents DOE/NASA CR-161546 Solar Energy System Performance Evaluation Seasonal Report for Wormser, Columbia, South Carolina; and Solar Energy System Economic Evaluation Final Report for Wormser, Columbia, South Carolina (CR# to be issued).

17. KEY WORDS

18. DISTRIBUTION STATEMENT
Unclassified-Unlimited

WILLIAM A. BROOKSBANK, JR.
Mgr, Solar Energy Applications Projects

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	105	NTIS

MSFC - Form 3292 (Rev. December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS:

List of Illustrations:

1.0 Introduction

This manual describes the theory and application of the "Pyramidal Optics Solar System", a term coined by Wormser Scientific Corporation to describe its unique scheme to capture, store, and release solar energy for space heating and domestic hot water. The theory of operation will be discussed in this introduction, with a detailed description of each subsystem following. The discussion will be aimed at the Contractor involved in his first solar installation, and the differences between solar and non-solar construction will be stressed. Reference will be made to the manufacturer of each critical component so that points not clarified by this manual may be referred to the equipment manufacturers or to Wormser Scientific Corporation. The information in this manual is not intended to be used for the design of a system, but is intended to supplement the working drawings, provided by the Architect or Wormser Scientific.

Principles of Operation

The solar energy incident on a house in the United States often exceeds the heating and cooling energy expended to keep that living space at a comfortable temperature. Using the inexhaustible energy of the sun for space heating and cooling becomes an increasingly attractive proposition in the face of escalating fossil fuel prices and diminishing supplies. The task of harnessing the energy of the sun in spite of its diffuse nature and time dependence (during good conditions, about 2,000 BTU/ft^2 fall on a horizontal surface per day; sunlight is available at useful intensities only eight hours/day) has received much attention by Wormser Scientific Corporation. Wormser Scientific has developed a patented system known as the Pyramidal Optics Solar Collection System.

The subsystems of this solar system deal with:

Collection: (support framing, solar windows, reflectors, absorber plates, collector pump, and piping, differential controller)

Storage: (water storage tank with its plumbing penetrations and insulation)

Distribution: pumps, domestic hot water preheat coil, controls and the Solar Auxiliary Unit containing dual source heat pump, direct solar coil and electric backup heating

These subsystems operate as shown schematically in Figure 1.1.

Collection

Sunlight enters the solar window, which consists of an array of 4' x 4' panes of ¼" plexiglass, held in place by a neoprene gasket. The rays are directed toward the absorber plate by carefully positioned reflective panels. These can be seen in Figure 1.2, a "Ray Tracing" diagram of the attic mounted Pyramidal Optics Solar System. Reflective surfaces are shown by dark lines. Fixed reflectors are attached to the northern rafters and to the floor. In addition, a moving reflector is shown in three of the angles that are set by the controlling unit, the Solar Altitude Compensator, throughout the year. The low angle occurs on December 21 each year, and the highest elevation occurs on June 21, with small weekly changes

in angle occuring automatically. The reflector surfaces form a truncated optical pyramid with the absorber at the apex or focus (thus the name "pyramidal optics"). Energy in the sunlight passing through the solar window reaches the absorber either directly or by reflection from the aluminized mylar reflectors. Angles of entry and reflection of the sunlight have been calculated so that nearly all the sunlight which passes through the glazing is concentrated on the absorber. The net optical gain after transmission and reflection losses is 3.0 in winter and decreases to 2.5 in the spring and fall, and 1.0 in the summer.

The energy of the sunlight impinging upon the selectively coated copper RollBond absorbers is released as heat. This heat is carried away by the circulation of the heat transfer fluid, pure water, flowing in water passages within the absorber plates. Pumped circulation occurs when a Differential Controller with sensors on the absorber and in the storage tank detects that the absorber temperature is ten degrees higher than the tank temperature, and therefore, that heat is available for collection. Circulation continues until the plate temperature falls to within two degrees of the tank temperature, whereupon circulation ceases. The water then drains back to the tank through sloping manifolds, providing protection against freezing.

Storage

The storage tank for hot water, usually located in the basement mechanical room, is a reservoir from which heat energy can be distributed to the heated space of the home or to the domestic hot water system on demand. The tank contains a volume of water approximately equal to two gallons for every square foot of solar aperture. Both wood and concrete tanks have been used successfully with the Pyramidal Optics Solar System. Waterproofing is achieved by the use of a single sheet of 1/16" thick EDPM sheet membrane which is draped into the tank, folded at the corners and attached to the upper edge of the tank with a strip of water resistant wood, such as redwood. The lid of the tank is waterproofed by a similar sheet, 3/64" thick. Plumbing penetrations are waterproofed using pipe seals supplied by the liner manufacturer, Carlisle Tire and Rubber Company. Insulation encases all sides of the tank, as well as the floor and lid. Before insulation of the waterproofing liner at least 4" of Styrofoam SM is placed in the floor of the tank. The walls and lid of the tank are insulated with four to six inches of urethane. After construction, insulation and waterproofing, the tank will contain water with enough heat to maintain house temperature during three successive cloudy days.

Distribution

Domestic hot water (for washing or kitchen use) is heated by solar energy in the following way. A closed loop of pipe connects a heat exchanger coil located in the solar storage tank with a heat exchange coil located in the bottom of the hot water heater as shown in Figure 9.1. A small pump circulates the water around this loop transferring heat energy from the storage tank to the hot water heater. A differential controller detects when the domestic hot water has reached the solar storage water temperature, shutting off

circulation. If the cooled water has not been warmed enough by the solar energy, a electric element in the top of the hot water heater comes on to bring the water up to the desired use temperature.

Space heating is accomplished using a unique "Solar Auxiliary Unit", developed jointly by Friedrich Air Conditioning and Refrigeration and Wormser Scientific Corporation. It consists of a dual source water-to-air and air-to-air heat pump combined with a water-to-air heat exchanger (called the "direct solar coil"), and a backup electric resistance heating strip. Because the temperature of the solar storage tank fluctuates widely during normal use, four different modes of operation are provided to permit the full utilization of the solar energy. The control system selects the mode most suited to the existing tank and outdoor temperature.

Mode 1

On those days when sunshine has added energy sufficient to raise the storage tank temperature above 85°F, space heating is accomplished by the direct use of the water in the storage tank. This water is pumped through the direct solar coil of the solar auxiliary unit where it gives up its heat to forced air circulated over the coil. Cool water is then returned to the tank for reheating. With the exception of the energy used by the pump and fan, heating in this mode is 100% solar powered.

Mode 2

If the temperature of the solar storage tank is between 40 and 85°F, the solar water cannot be used directly to produce sufficiently warm air for space heating. This water, however, still contains considerable heat energy which can be captured by means of the heat pump which, through its refrigerant compression cycle, produces high temperature heat from the low temperature water. Water between 40 and 85°F is circulated through the heat pump which extracts heat from it and uses the heat to warm the building air supply at a heat exchanger surface in the cabinet.

Mode 3

When the solar storage tank temperature falls below 40°, little more energy can be withdrawn before ice crystals begin to form. If the outside temperature is above 10°F, the heat pump switches to a heat exchanger located out of doors and operates in an air-to-air mode, much like an air conditioner turned inside out. Low temperature heat is withdrawn from the outside air and high temperature heat is produced in the cabinet-mounted heat exchanger mentioned in Mode 2.

Mode 4

When the tank temperature is too low to provide heat energy (below 40°F) and the outside temperature is colder than 10°F, the controls activate the backup electric resistance elements located in the heat pump cabinet. These resistance elements provide heat capacity to maintain comfort conditions during rare periods of extended overcast and low outdoor temperatures.

Typical Applications

The Pyramidal Optics Solar System is adaptable to a wide variety of housing designs. The collection system may be a single unit or may be composed of a number of solar windows, each with its associated reflectors, absorbers, and piping. The schematic design shown in Figure 1 is amenable to use in a single family home or in multi-family dwelling units. The latter will be discussed in this manual.

Four-Unit Townhouse Condominium

The Pyramidal Optics Solar System is employed in multi-family dwellings near Columbia, South Carolina. A photograph of a four townhouse building, at the Yacht Cove Development on the shores of Lake Murray, is shown in Figure 1.3. It consists of two end units with 2,530 square feet of occupied space on two floors and two middle units of 1,570 sq. ft. on three stories. The building uses two Pyramidal Optics Concentrating type solar collectors which have been installed in the attic space of the two end units. The solar system was incorporated without significantly changing the architectural design, and the solar buildings (two have now been completed) blend aesthetically into the 400-unit Yacht Cove townhouse project.

A necessary prerequisite to installing solar heat is the thorough insulation of the building. In the Yacht Cove buildings, the normal 3 1/2" of fiberglass in the walls was supplemented by the addition of a 3/4" layer of tongue and groove styrofoam on the outside of the frame wall. This increased the insulation value of the wall by 40% and significantly reduced infiltration. Single panes of glazing were replaced by dual panes throughout. This feature, combined with the addition of overhangs to shade the windows in the summer, further reduced winter heat losses and summer heat gains. The thermal improvements in building construction are credited with an overall reduction of heat losses of 45%.

A sectional view of the four-unit building is shown in Figure 1.4 and illustrates the apartment at the east end of the structure. The solar collection system is seen occupying the unused attic space. Reflective aluminized mylar covers the interior surfaces of the attic. This material concentrates the solar energy by a factor of four onto an array of 12 selectively blackened copper absorbers. The solar window of 1/4" thick plexiglass measures 36' x 16' for a total area of 576 sq. ft. The combined solar windows have an area that is 14% of the heated floor area of the building.

The solar heat collection and storage system of the building will supply 60% of the average heating load from sunlight. This figure is based on a total heating load of 21×10^6 BTU/month, and a peak heating load of 106,000 BTU/hr.

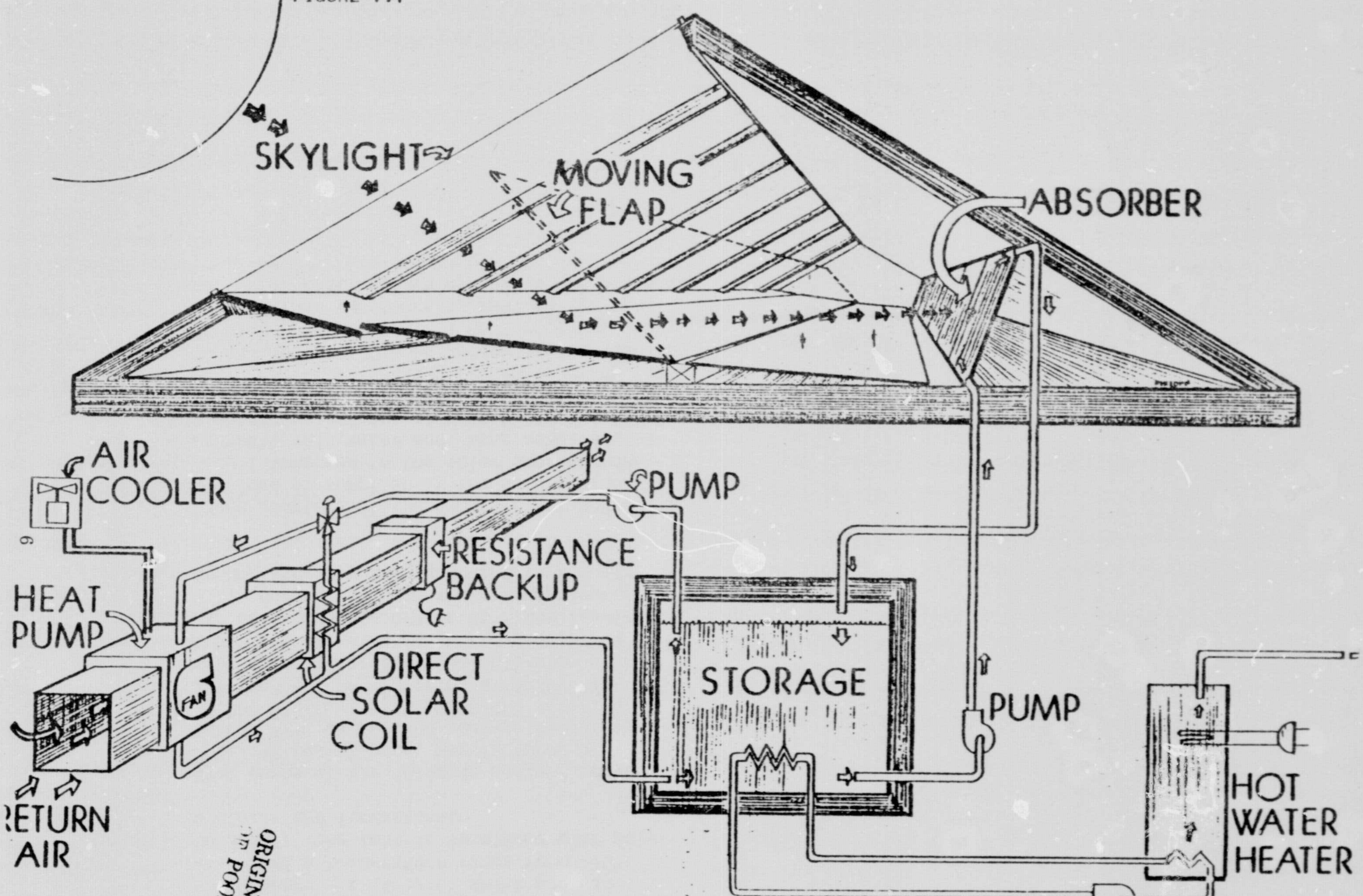
The storage tank is a 2,500 gallon reinforced wood container, waterproofed by "Sure Seal EPDM sheet

membrane" manufactured by Carlisle Tire and Rubber. It is 1/16" thick and can withstand a temperature range from -75° to 300°F. The tank is insulated with polyurethane and isocyanurate.

Heat pumps of the "Climate Master" series Model 42 Dual Source, manufactured by Weil McLain are used. The heating output is 38,000 BTU/hour with 1,200 CFM entering at 70°F and 5.7 GPM entering at 60°F. The cooling capacity is 32,000 BTU/hour with 1,040 CFM entering at 80°F dry bulb and 67°F wet bulb, and 4.4.GPM at 75°F and leaving at 95°. During the summer air conditioning is accomplished by the equipment in the air-to-air mode.

Three-quarters of the domestic hot water heating load is supplied by the solar system. A coil immersed in the solar storage tank preheats this water and, when required, an electric resistance element heats the water to use temperature. The design of the domestic hot water heating system provides that 50 gallons at 120°F or hotter can be supplied to each apartment with a heat recovery time of less than two hours to meet an average hot water heating load of 3.02×10^6 BTU/Month.

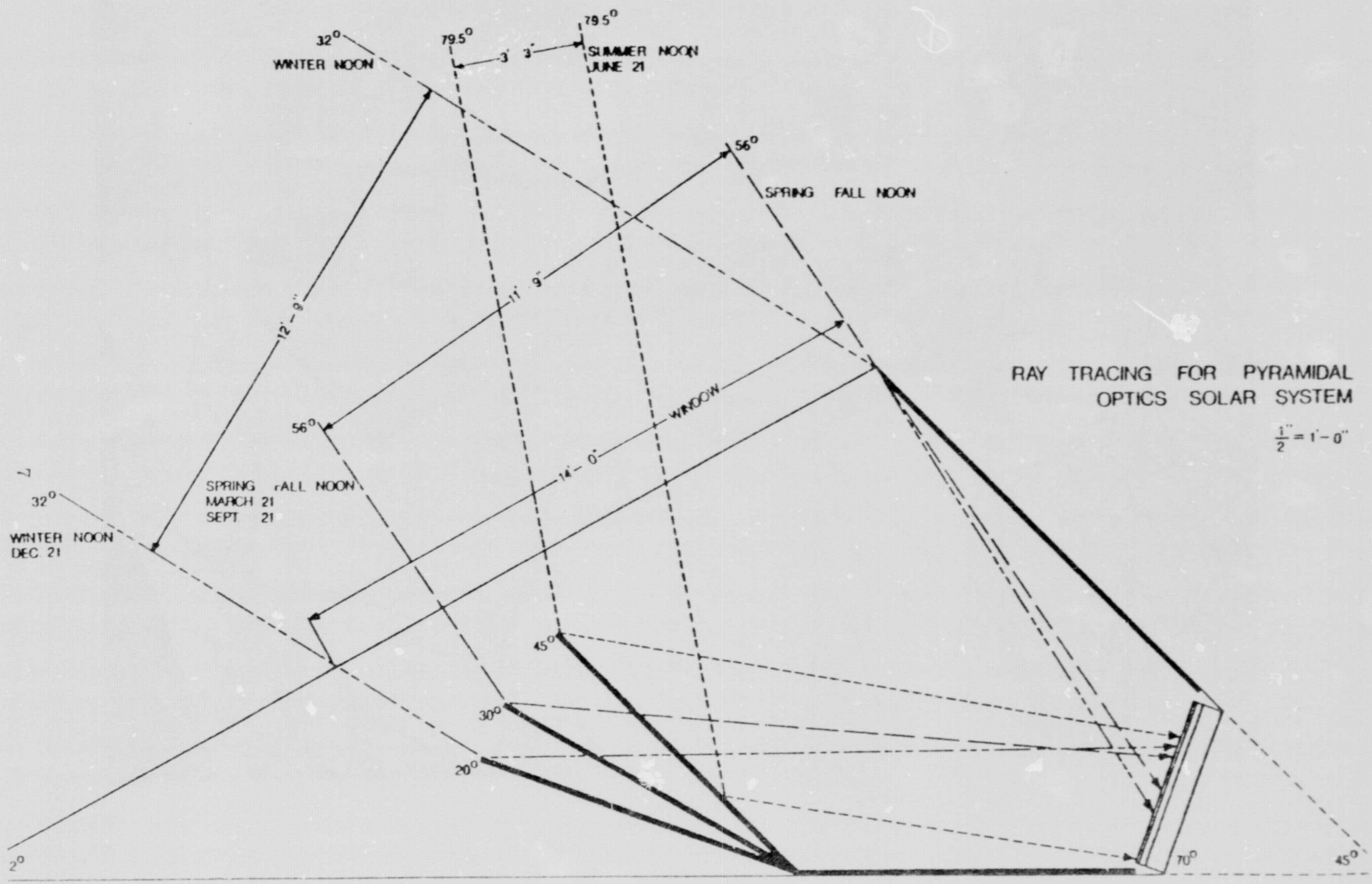
FIGURE 1.1



PYRAMIDAL OPTICS SOLAR SYSTEM

U.S. PATENT 3,841,302 WORMSER SCIENTIFIC CORP. 203 329 2001

FIGURE 1.2



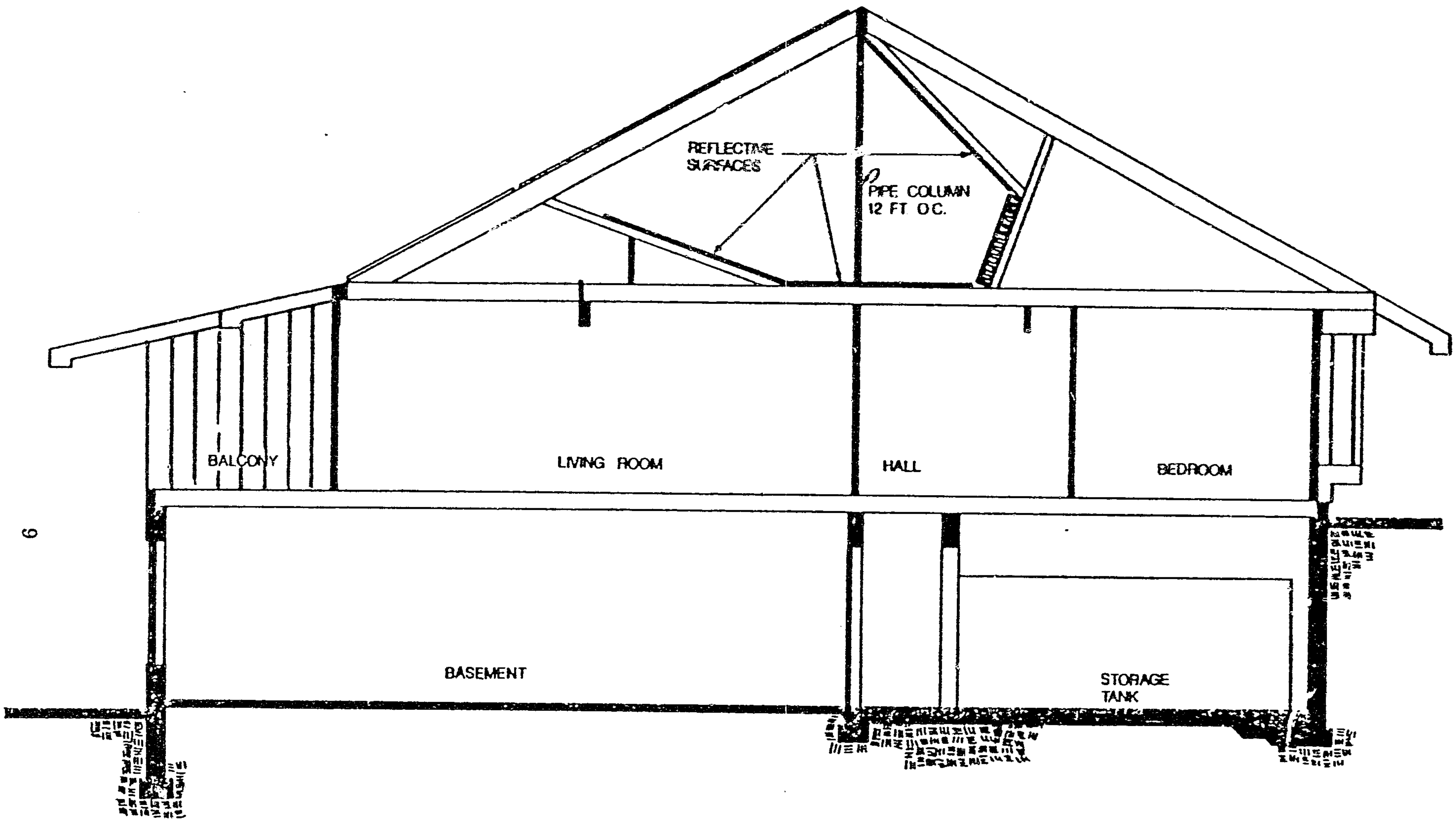
RAY TRACING FOR PYRAMIDAL OPTICS SOLAR SYSTEM

$\frac{1}{2}'' = 1'-0''$

FIGURE 1.3

4 UNIT TOWHOUSE CONDOMINIUM

FIGURE 1.4



SECTION AT DOWNHILL SOLAR UNIT: TYPE 2

$\frac{1}{4}'' = 1'-0''$

2.0 Sequence of Installation

Figure 2.1 gives a diagramaticillustration of the sequence of installation of the Pyramidal Optics system. Many items can be done concurrently.

The first step in the installation of the system is the pouring of a slab at the location of the storage tank. This must be of sufficient thickness and contain sufficient reinforcement to support the concentrated weight of the storage tank, and should be separated from the poured concrete floor of the basement. (This operation minimizes the effects of differential settling of the tank slab.)

The attic framing is the next construction step that directly affects the solar system. The section in this manual describing the attic framing should be carefully studied before beginning this work, since there are some steps which require more precise carpentry than would be necessary in constructing a non-solar attic. After the attic is framed, the framing of the supports for the collector and reflector can proceed concurrently with the installation of the glazing of the solar window.

The construction of the storage tank can proceed concurrently with the attic framing, including the placement of the waterproofing liner. With the completion of these steps the solar installation must wait until the building is completely dried-in.

After the building is sealed from the weather, many tasks may proceed, most of them simultaneously. The absorbers can be installed and piped, plumbing to the absorbers may be connected, and the auxiliary unit may be installed. Wiring for both power and system controls may be run.

Following the completion of these tasks, the plumbing may be tested for leaks, and any leaks that are discovered fixed. The vents and gauges required for proper system operation can then be installed. After these steps are complete, the pipes may be insulated.

At the same time that the above steps are proceeding, the reflective material in the solar collection system may be installed. This includes both the fixed reflectors and the moveable reflective flap. The sequence of installation for the moving flap should be: framing of the aluminum members and their attachement by hinges to the wood supports installed previously, installation of the reflective material in the frame, affixing of the pulleys and the stringing of cables through them for the changing of the angle of the flap, and finally, attachment of the Solar Altitude Compensator to both the cables and the flap.

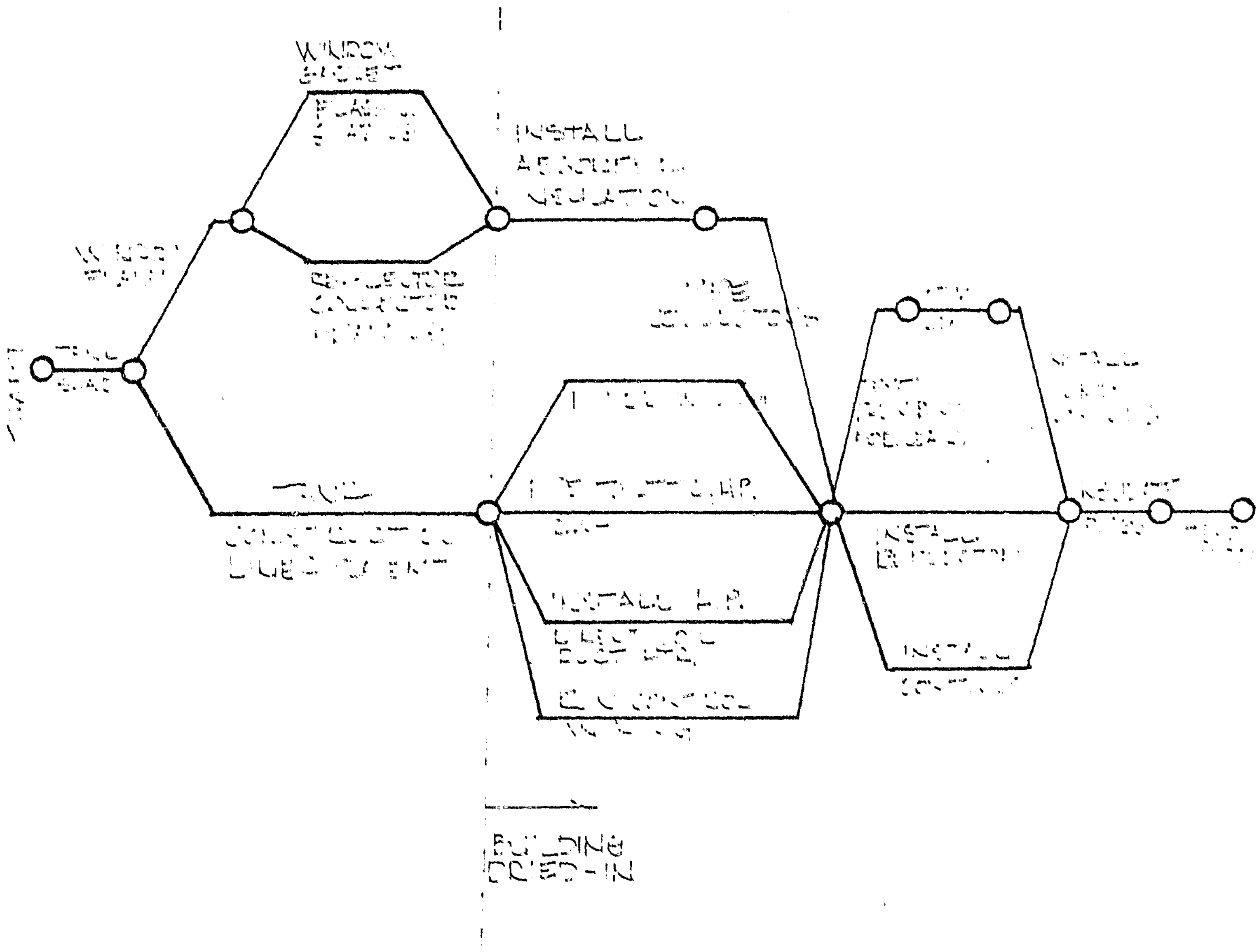
The system operating controls may be installed next. The last step is the filling of the system with water and the testing of the operating modes to verify that each component is performing as expected.

The steps described above are pictured for easy visualization in a flow chart format in Figure 2.1. On this chart time flows from left to right. Tasks are indicated by lines between the nodes, which are drawn as circles. All tasks to the left of a

node should be completed before any task to the right of that node is begun. For the most smooth integration of the solar installation with the construction of the building, it is suggested that the flow chart pictured in Figure 1 be incorporated into the flow chart for the entire job before the beginning of construction.

FIGURE 2.1

Sequence of Installation of the Pyramidal Optics Solar System



On this chart time flows from left to right. Tasks are indicated by lines between nodes (circles).

3.0 Storage System

Instructions are given below for construction of a wood tank. The volume of this tank is 2,500 gallons.

Installation

1) Walls and Tops:

Construct tank walls and top and foam-in the insulation while the sections are in a horizontal position, as shown in Figure 3.1. Be sure that the 3/4" inside wall plywood of the long side extends beyond the short wall to provide a strong corner. See Figure 3.2. Be sure that all screws are countersunk so that no heads protrude into the tank cavity.

The top should be built in sections small enough to transport each of which can be built in another part of the building and carried to the mechanical room. If the top is built in four sections, each 4' x 7', each piece should be small and light enough to handle. Gluing the membrane to the top will be covered below.

2) Tank Floor:

Lay out polystyrene (Styrofoam SM or TG) on mechanical room floor to a thickness of 1½". This material protects the tank from floor moisture. Temporarily support the 3/4" flooring plywood on concrete blocks (or other support) above the floor as shown in Figure 3.3. This will permit easy assembly of the walls to the bottom plywood as explained below. These floor plywood sections must span the 7' dimension of the tank to prevent the tank walls from bowing.

3) Set Up of Walls:

Position the walls on 3/4" bottom plywood and tack to hold in position for the bolting (Step 4). Be sure that no screw heads protrude into the tank where they might puncture the bladder. See Figure 3.4.

4) Bolting:

With the tank walls tacked in place, bolting can now be accomplished. Drill from the underside through the plywood and bottom 2 x 6 plate. See Figure 3.5. To get the washer and nut onto the bolt, a small amount of insulation will have to be cut out above each bolt. Similarly, bolt the corners at the top plate.

5) Lower the Tank:

When this bolting is finished, the supports can be removed, and the tank can be lowered onto the styrofoam. Lay or foam-in the inside floor insulation. Nail on exterior plywood (except around the top). At this point, nearly all carpentry and all insulating should be complete.

6) Instructions for Attaching the Membrane:

The list of materials from the rubber liner manufacturer, Carlisle, is as follows:

Quantity	Description	Remarks
1	1/16"thick EPDM rubber sheet 18'-0" x 26'-0"	This piece is tank bottom liner.
1	3/64"thick EPDM rubber 7'-0" x 16'-4"	This piece will cover the lid.
1	Gal N-100 Splicing Cement	This material is for cementing rubber to rubber as attaching pipe seals and sealing seams in the tank top.
1	Ctn. Lap Sealant	This material is to be spread along rubber to rubber seams.
1	Ctn. Water Cut-off Mastic	This material will be applied to the pipe during attachment of pipe seal.
4	1" dia. prefabricated Pipe seal	These are preformed gaskets which slide over pipe end and seal to tank wall.
2	2" dia. prefabricated pipe seal	"
2	Gallons 90-8-30-A Bonding adhesive	This material is a contact cement for rubber to wood cementing. It will be used on the cover assembly.

You will need to have on hand six (6) stainless steel pipe clamps for pipe installation.

7) Attachment of Rubber Liner to Top:

Unroll the 7'-0" x 16'-4" membrane in a clean, swept area and allow it to "relax" until it lies flat. Sweep off excess white talc powder.

Four sections need to be cut to attach the four cover pieces. To seal the seams, three of these pieces should be cut slightly wider than the 4' plywood to form a lap. Cut three pieces 4'-1¼" x 7'-0" and one piece 4'-0" x 7'-0" as shown in Figure 3.6.

Attach these pieces to the cover sections as follows:

a) Lay the wood cover sections flat on the floor with the inside tank plywood facing up. Clean off all dirt.

b) Lay the rubber sheet on the plywood and position carefully so that three edges are flush. One edge will hang over 1¼". Place some heavy weights along the 7' flush edge to hold the rubber in position. Roll back the rubber sheet to expose half the plywood as shown in Figure 3.7.

c) With paint roller, roll a thin layer of

90-8-30-A Bonding Adhesive onto exposed plywood and onto exposed rubber, Figure 3.8. (Avoid cementing the last 1¼" which will hang over. This overhand will later be glued to an adjoining panel with splicing cement.) This Bonding Adhesive should be of uniform thickness without blobs or thick areas. Allow the adhesive on both surfaces to dry, at least 20 minutes. Test for dryness by touching lightly with a knuckle. DO NOT MATE SURFACES WHILE ADHESIVE IS WET.

d) Begin rolling the rubber down onto the plywood, starting from the center and moving toward the edge, Figure 3.9.Do this carefully so as to avoid wrinkles. This contact adhesive is permanent. YOU HAVE NO SECOND CHANCE. Once the rubber is down, it cannot be removed or repositioned.

e) After one side is firmly attached, repeat this procedure on the other side. Repeat on the other three cover panels. (One panel will have its rubber sheet flush all around.)

f) These cover panels are now ready to lift onto the tank bottom.

8) Tank Liner Installation:

Workers should wear sneakers when walking on rubber liner and should be encouraged to avoid dropping sharp tools or materials on the membrane.

Liner is 18'-0" x 26'-0". Drape into tank and fit into corners. Neatly pig-ear corners (Fold like a Christmas package.) Figure 3.10. Using brass screws, attach the retaining redwood strip around the top of tank. The rubber liner should be folded over the top plate all around, Figure 3.11. When the cover sections are lifted on, this will form a rubber-to-rubber seal.

9) Pipe Seal Installation:

Pipe seal is accomplished as follows:

Cut pipe hole no larger than pipe. Thoroughly clean the area 12" around the hole with a rag until the area is free of dirt and dust. Use Heptane or white gas as a solvent cleaner on rags. Insert the pipe into the tank several inches beyond the length of the pipe seal. Stir splicing cement thoroughly before using. Apply by 3" paint brush, brushing in a circular motion, a liberal uniform coat of splicing cement to the area around the hole and the mating surface of the pipe seal. Allow the cement to dry until it does not stick to a dry finger touch. Maximum time between application of cement and the mating of the two surfaces should not exceed 30 minutes. DO NOT MATE SURFACES WHILE CEMENT IS WET.

After cement is dry to the touch on both the tank membrane and the pipe seal, slide the pipe seal over the pipe. Press the pipe seal firmly to tank wall. Apply lap sealant to perimeter of pipe seal splice area.

Now complete the closure at the pipe. Slide the

pipe seal over the pipe. Press the pipe seal firmly to tank wall. Apply lap sealant to perimeter of pipe seal splice area.

Now complete the closure at the pipe. Slide the pipe seal down the pipe to expose 2" of pipe. Apply water cut off mastic all around the pipe. Slide the pipe seal back over the mastic and clamp with a stainless steel clamping ring. Apply lap sealant at the end of the seal all around, see Figure 3.12.

10) Cover Installation:

Carefully lift cover panels in place. Toe nail every 6" with 20d nails all around. Angle nails so that they do not penetrate inner membrane, Figure 3.13. Seams between cover panels should now be sealed. Apply splicing cement to $1\frac{1}{4}$" flap and mating surface. Allow these surfaces to dry. DO NOT MATE SURFACES WHILE CEMENT IS WET. Press surfaces together to seal joint. Apply a bead of lap sealant to seam to complete job.

11) Pipe Seals in Cover:

Install as in Step 9.

Tank Operation

The operation of the tank is automatic.

Tank Maintenance

A periodic check of the tank water level should be made by a check of the sight glass. If local plumbing codes permit, an automatic float valve can be installed to maintain the tank water level. If no cross connection is permitted, make up water can be added by hand to compensate for small evaporative losses. Water quality should be tested before initial filling to determine whether an ion exchange treatment is required. The pH of the water should be between 7.0 and 7.4, and the mineral content should be low. Water quality should be retested annually (more frequently in areas of difficult water conditions). NEVER ADD ANY TOXIC SUBSTANCES TO THE SYSTEM WATER. In the unlikely event of multiple pipe leaks, toxic substances could pose a hazard.

FIGURE 3.1

FOAMING-IN OF WALL INSULATION

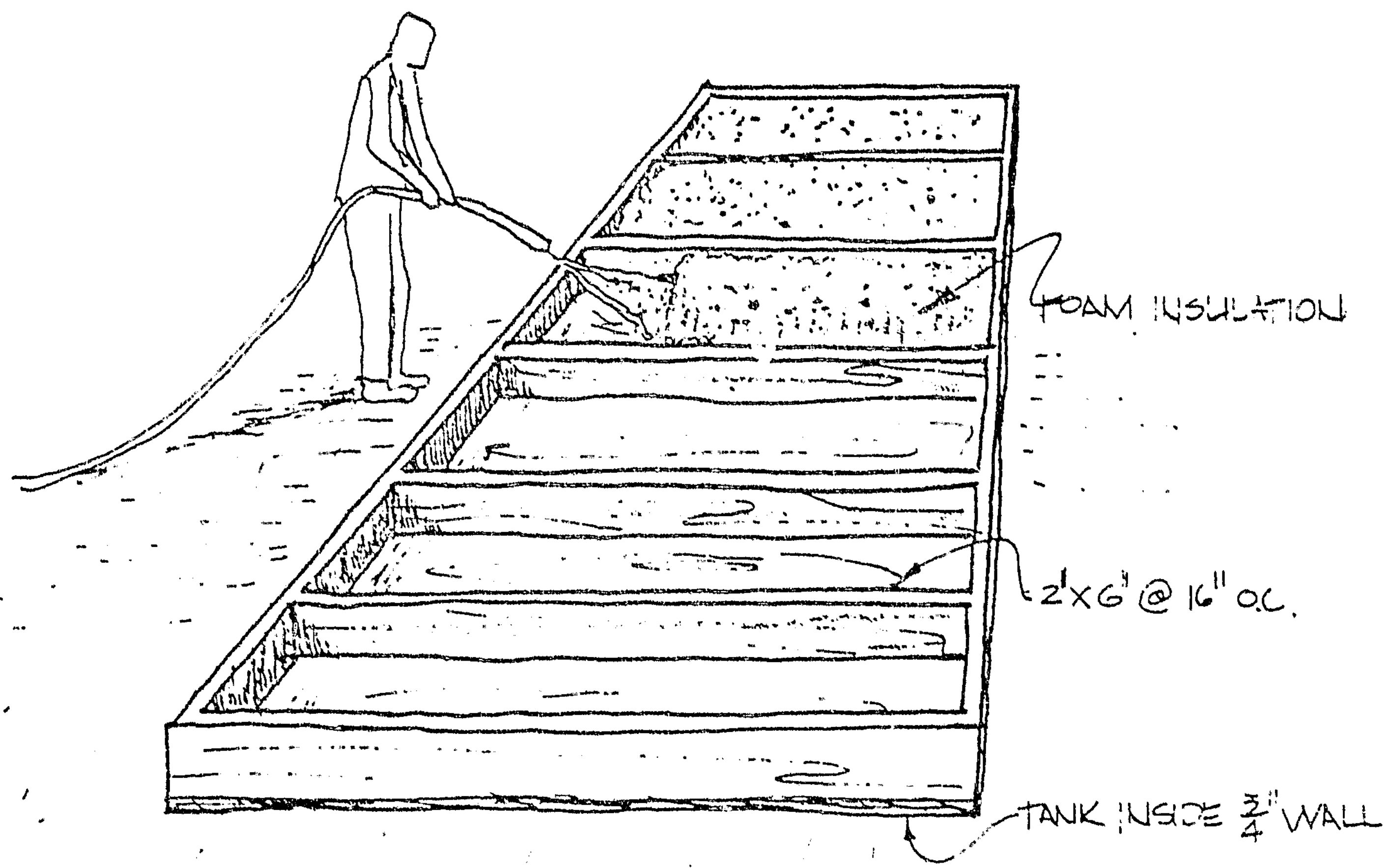
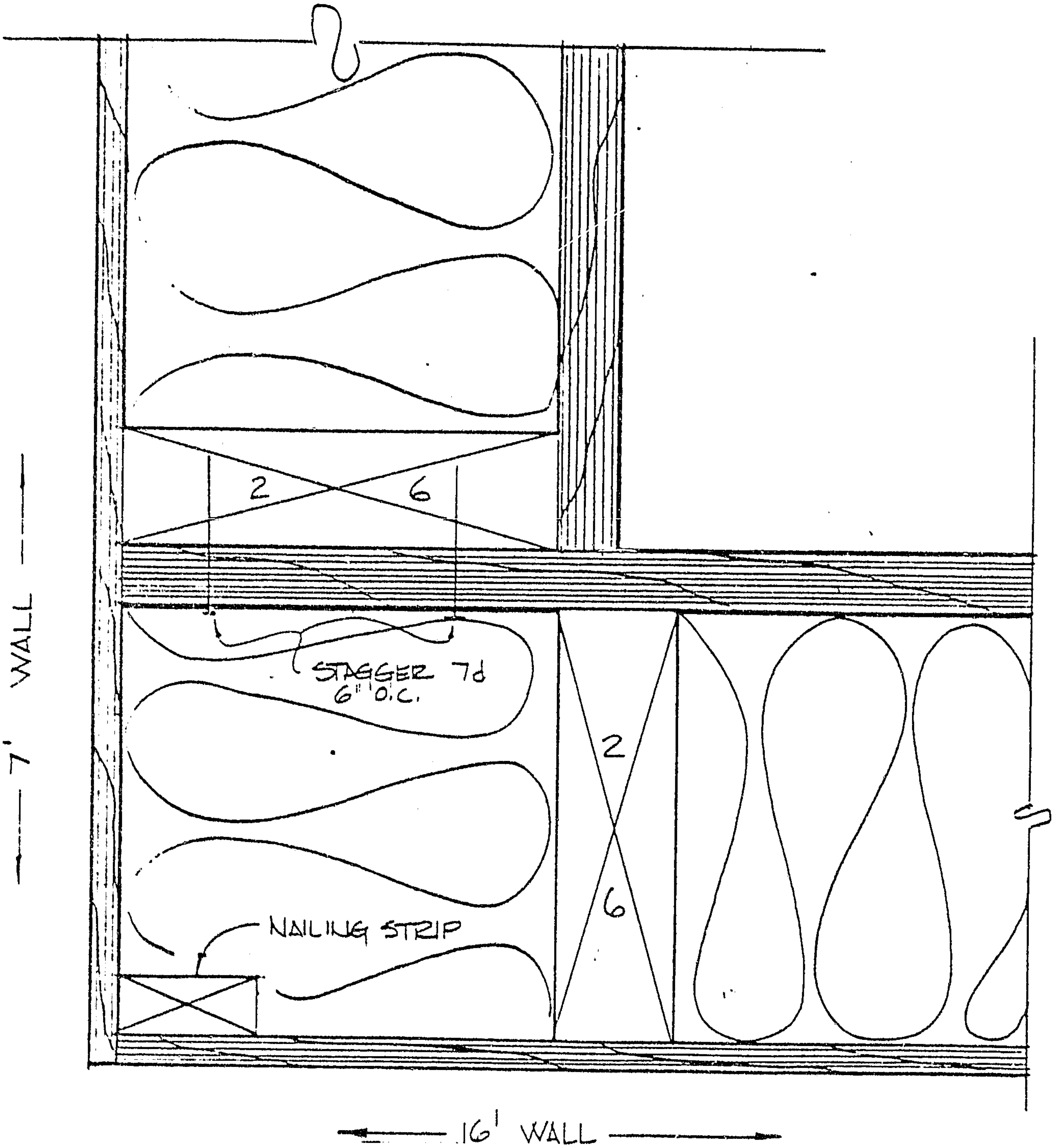
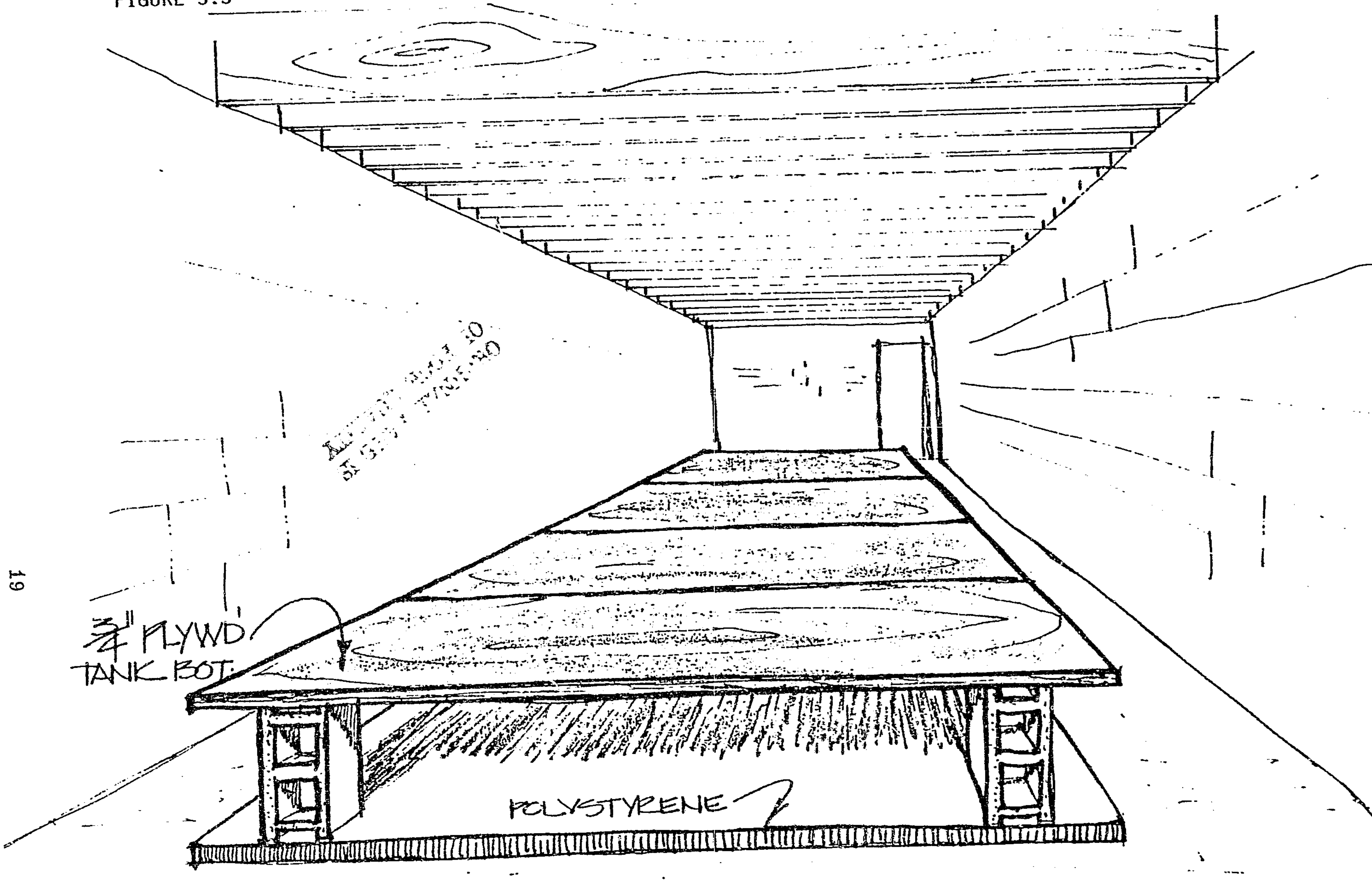


FIGURE 3.2

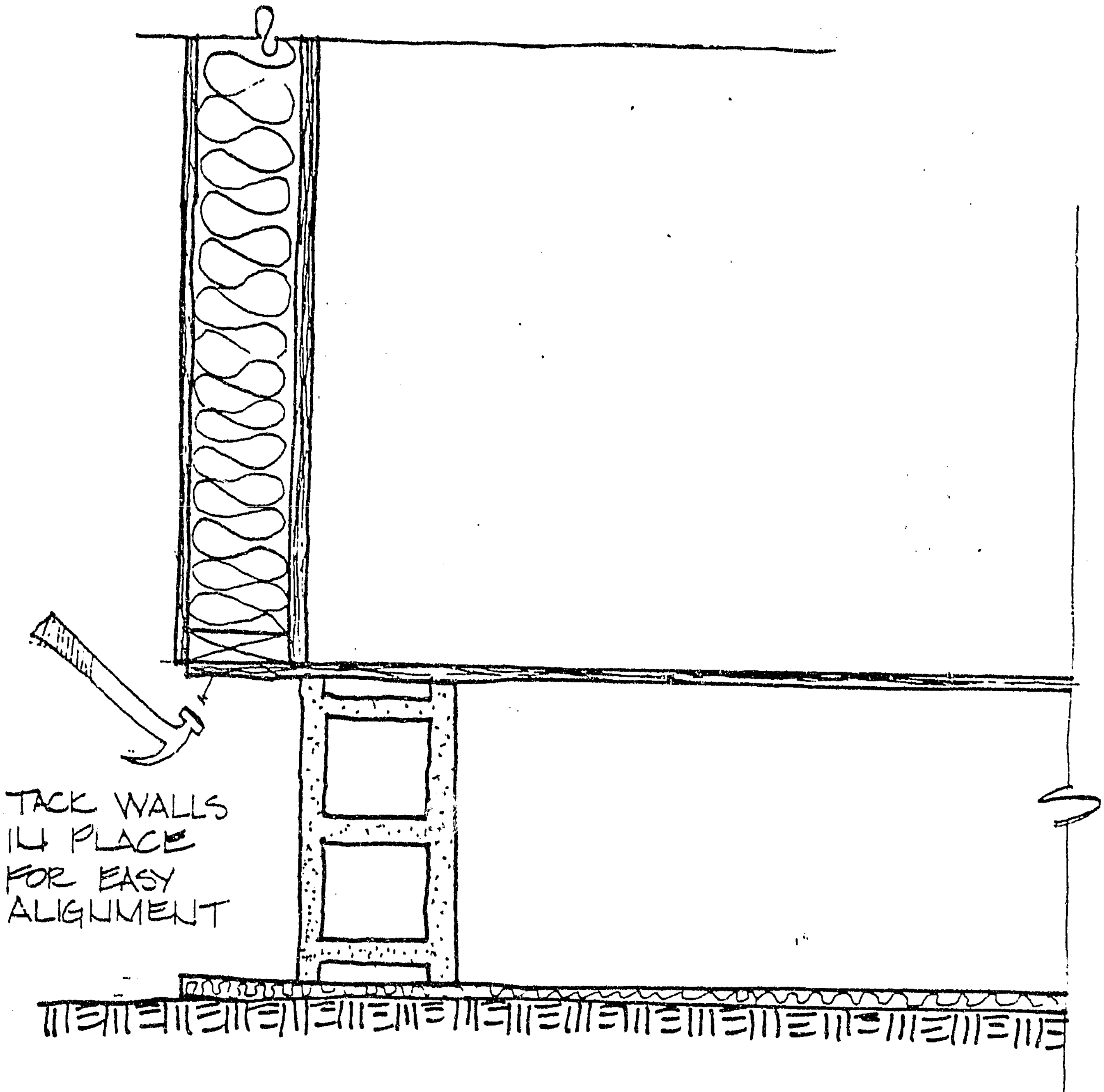


CORNER DETAIL-PLAN VIEW

FIGURE 3.3



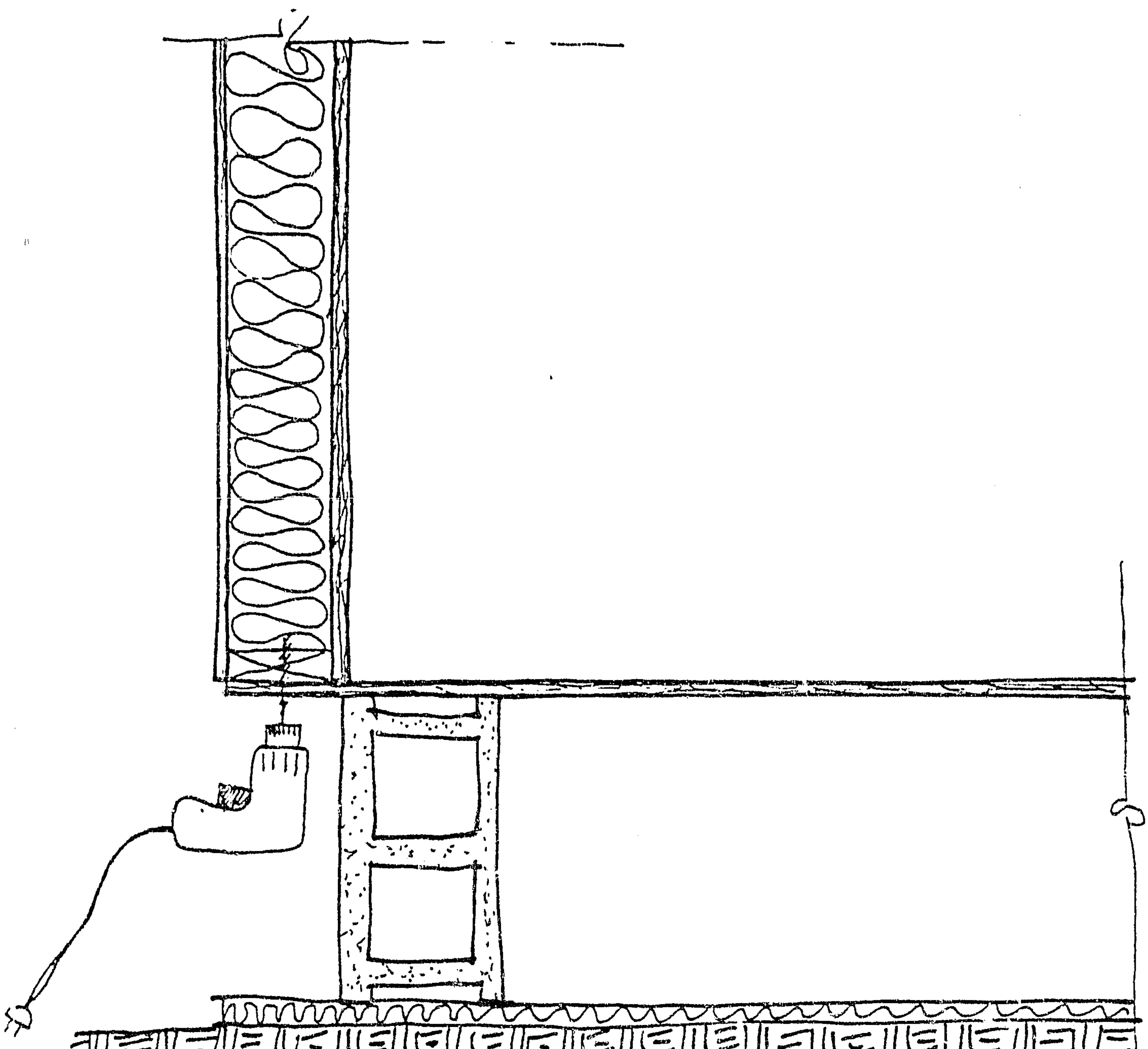
TANK FLOOR RAISED ON BLOCKS



ERECTION OF WALLS ON FLOOR

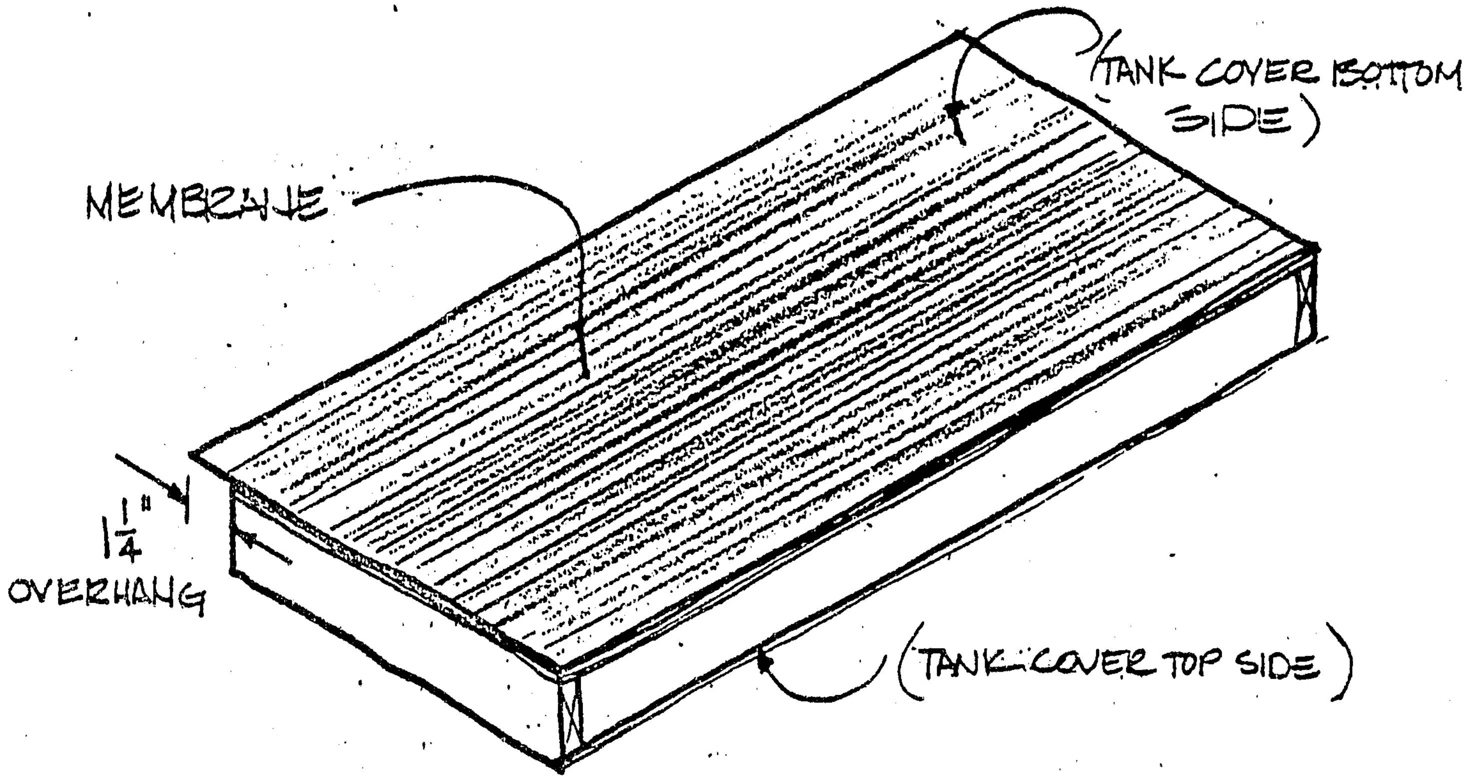
FIGURE 3.4

FIGURE 3.5



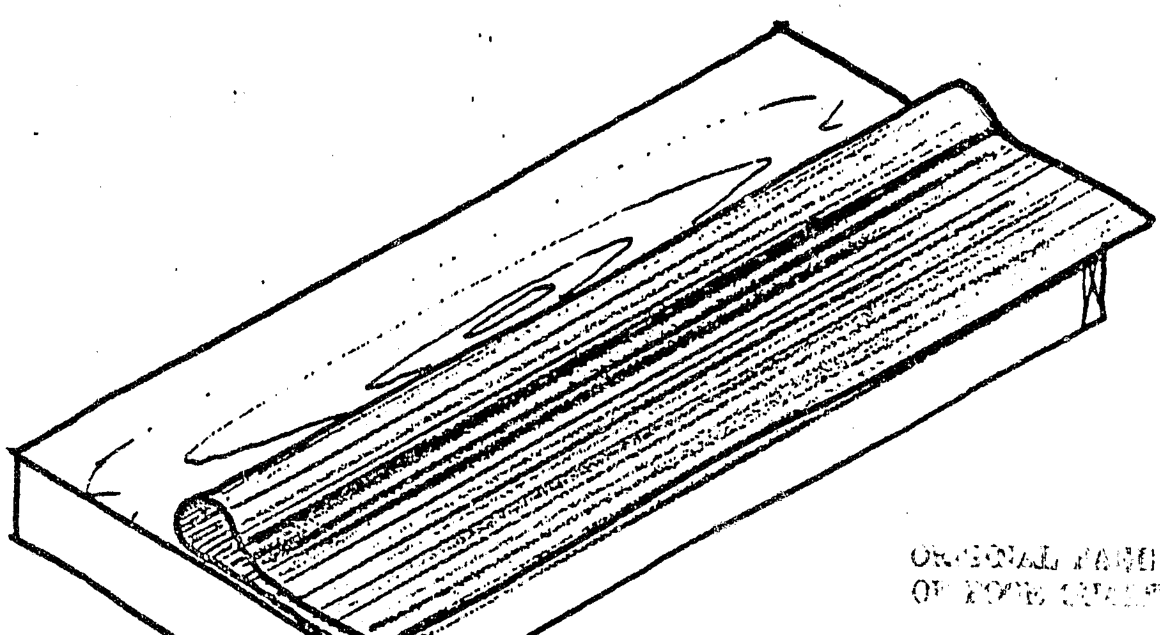
BOLT THROUGH PLYWOOD INTO PLATE

FIGURE 3.6

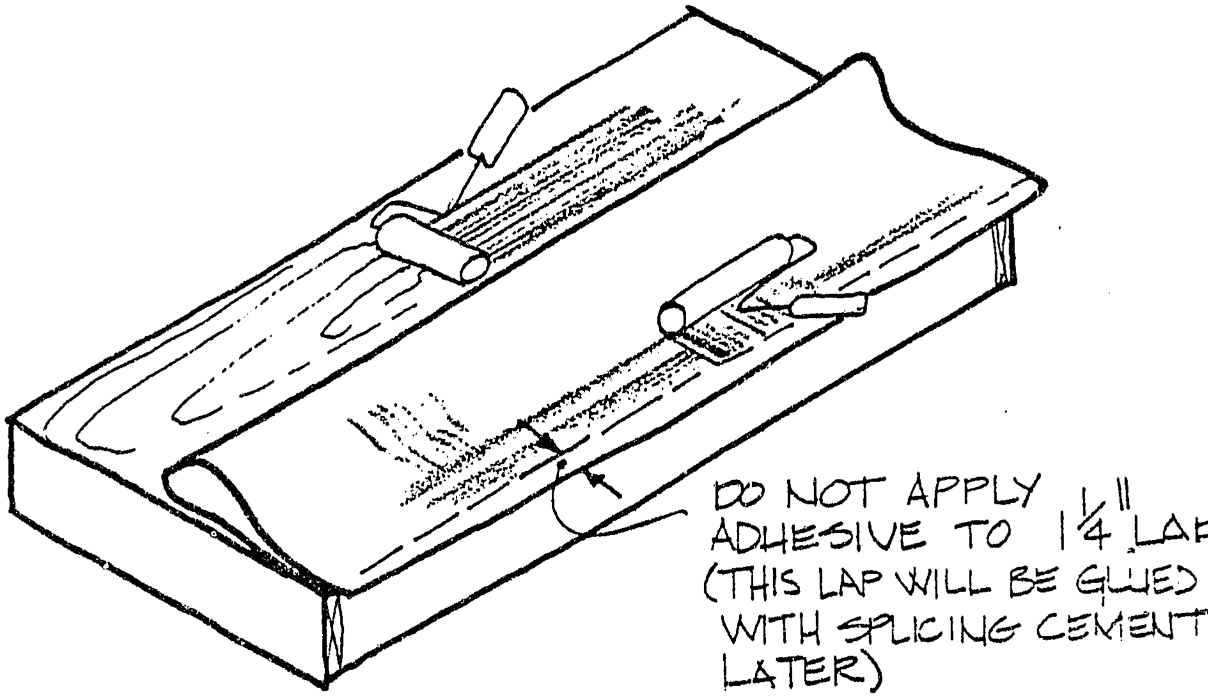


LAY OUT MEMBRANE FLUSH ON 3 SIDES

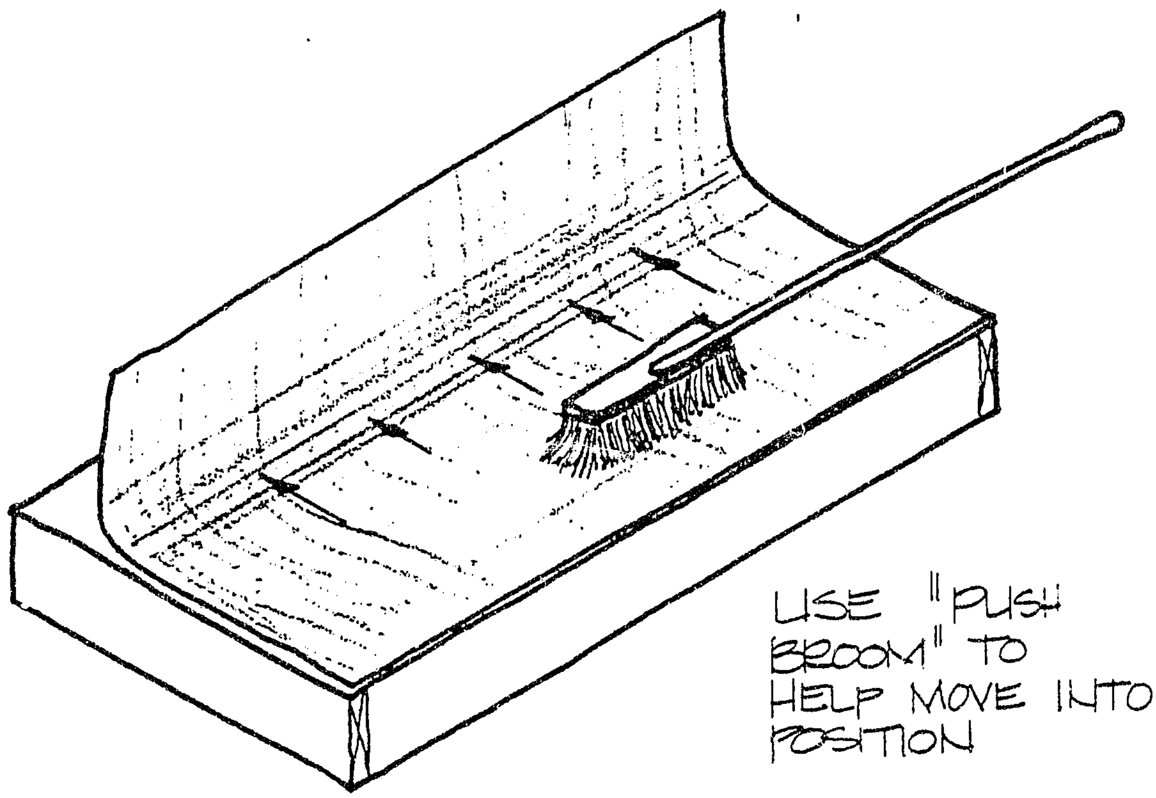
FIGURE 3.7



PULL BACK TO EXPOSE ½ OF COVER



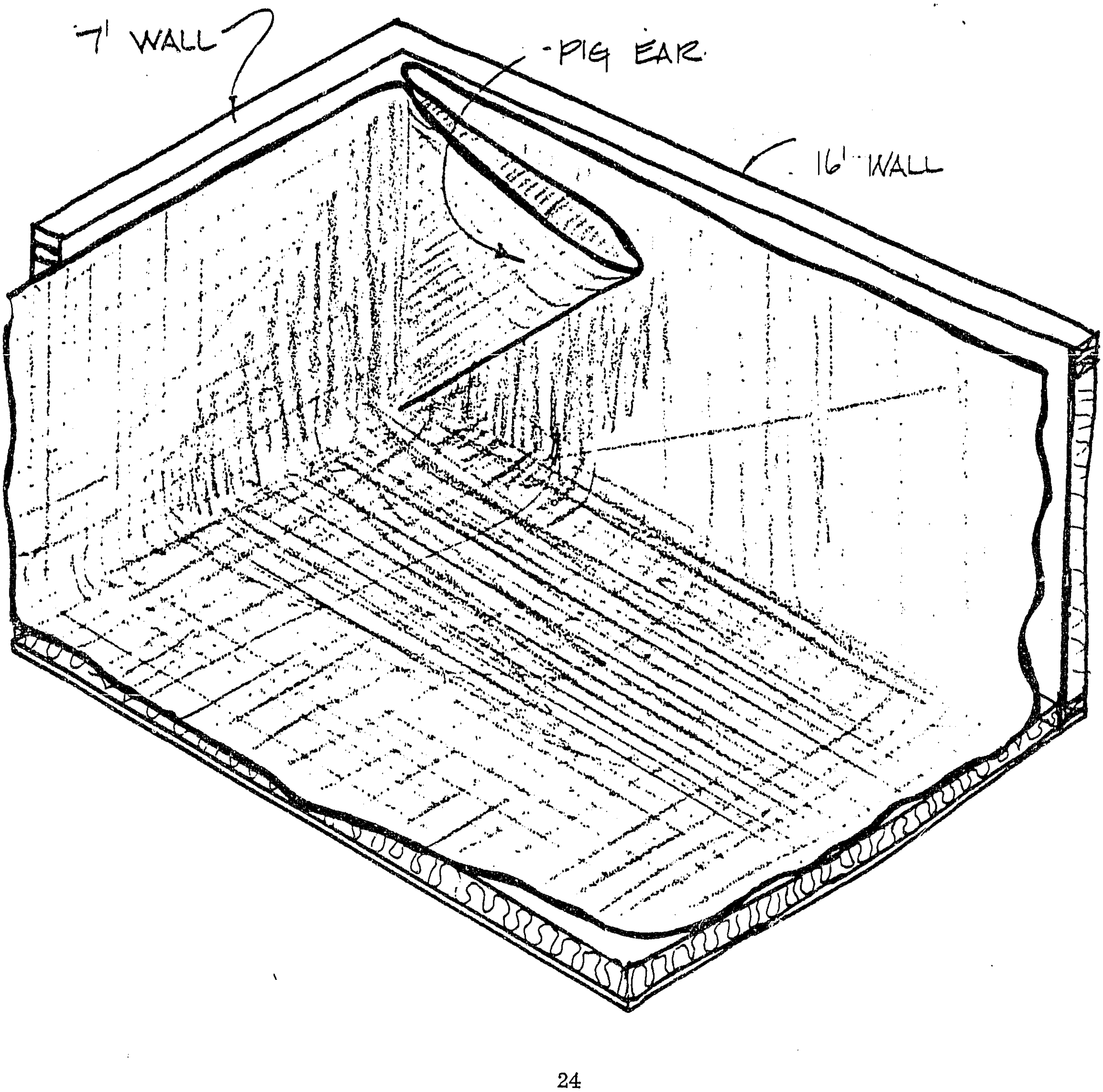
ROLL ON BONDING ADHESIVE

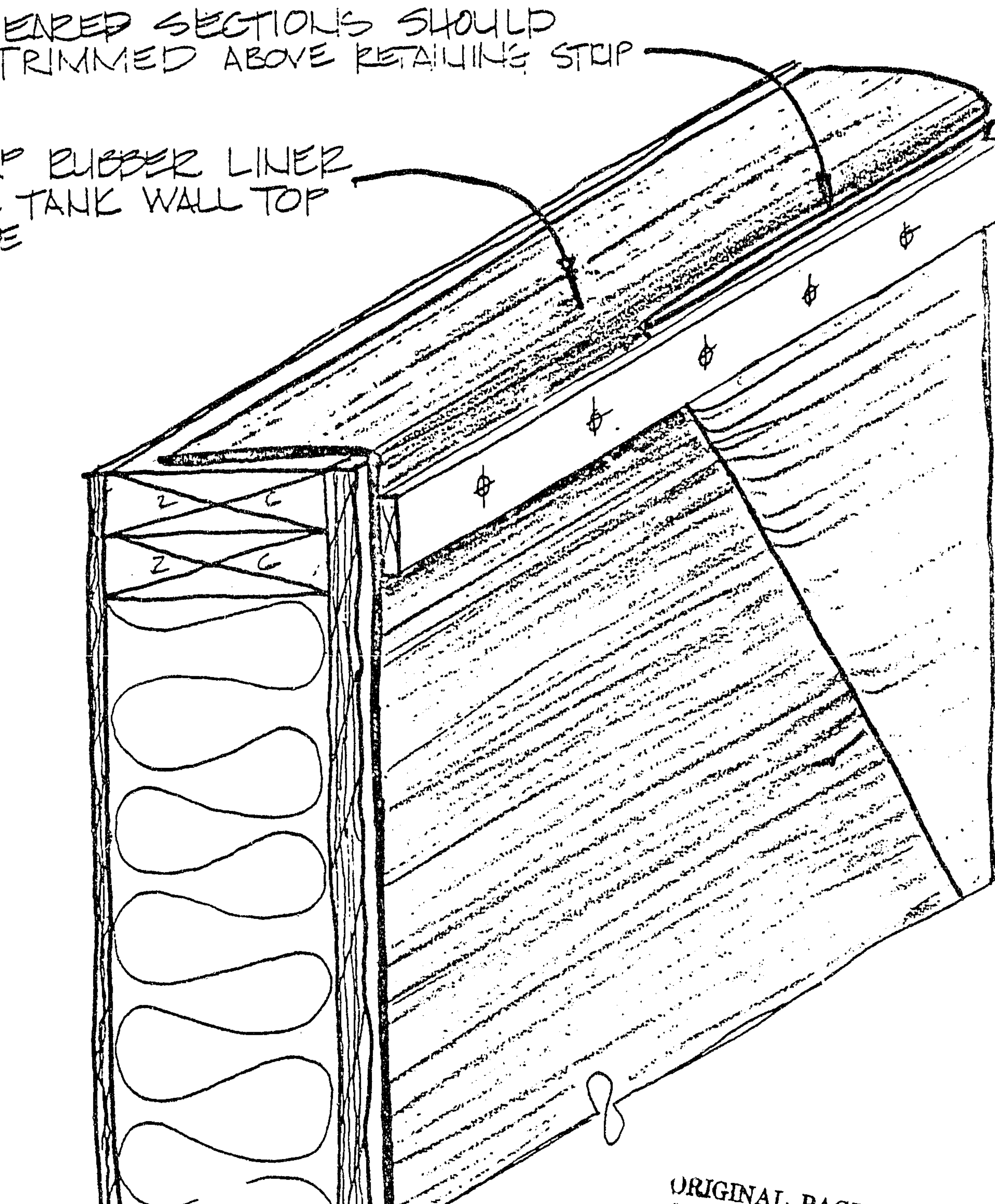


CAREFULLY ROLL RUBBER INTO PLACE

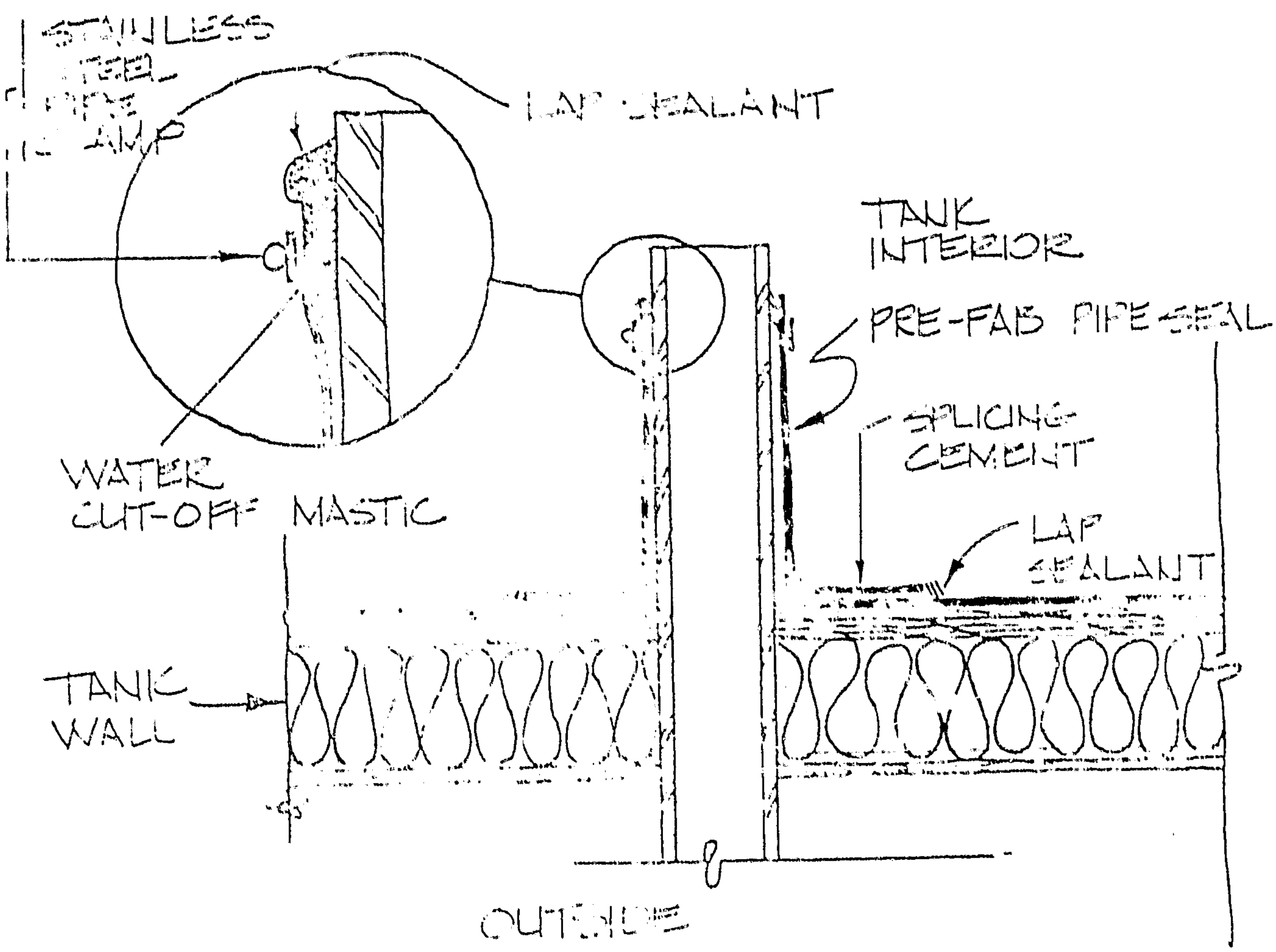
CORNERS SHOULD BE "PIG EARED"

FIGURE 3.10

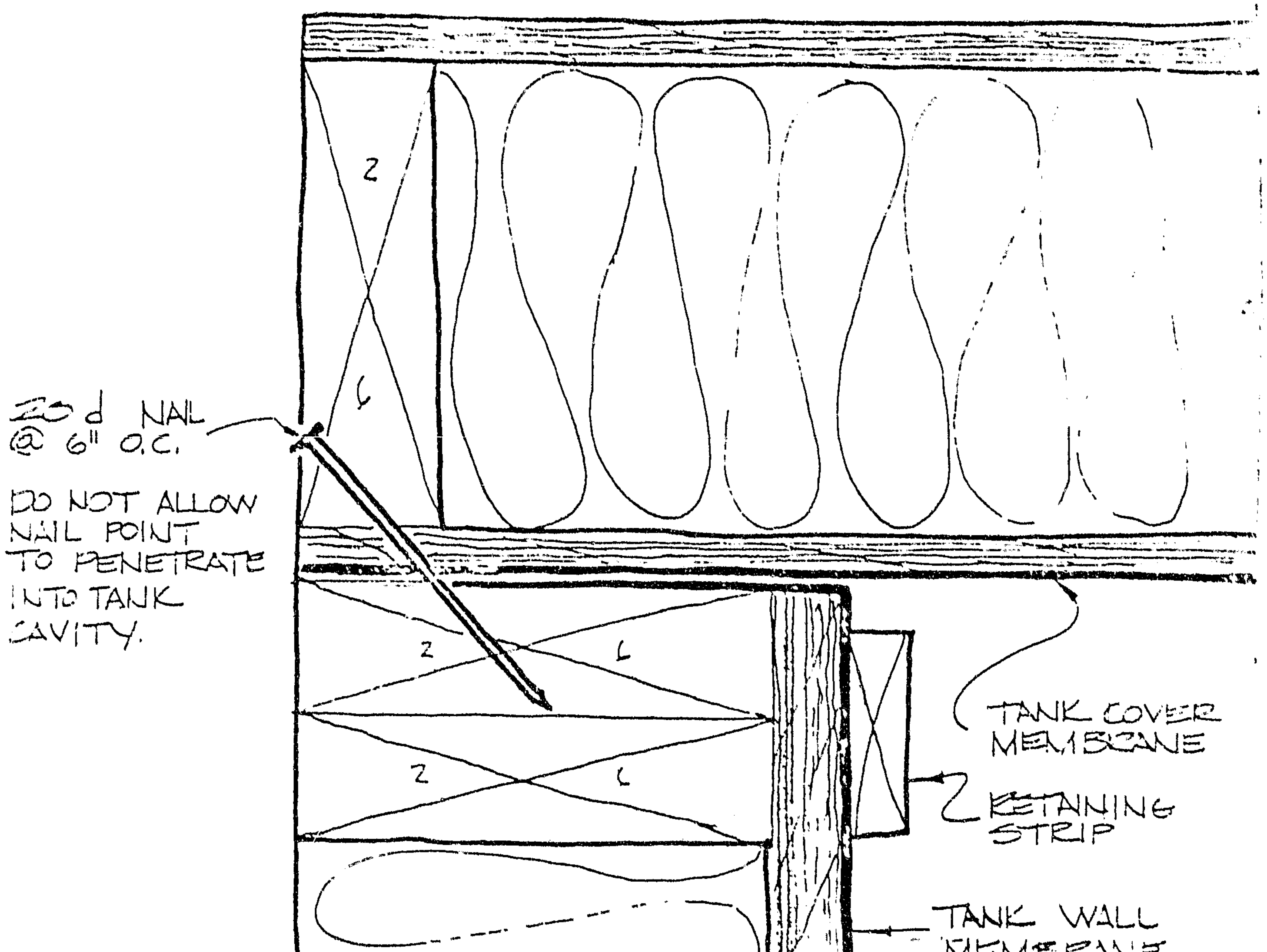




CARRY RUBBER OVER TOP PLATE



PIPE SEAL INSTALLATION



SECTION AT TOP EDGE OF TANK

4.0 Attic Structural Support System

Installation

Window Supports:

The principal difference between the framing of the attic on a home using the Pyramidal Optics Solar System and the framing of an attic without this feature is the degree of precision required. The solar window of the Pyramidal Optics system is glazed by the installation of a grid of 4' x 4' squares of plexiglass held in place and waterproofed by a lock strip "zipper" gasket. This gasket is held in place by aluminum channels that are screwed to the attic rafters. These channels must be attached at exactly 4'-0" centers for the subsequent installation of the gasket and glazing to be successful. The attic is, therefore, framed in the conventional manner, but with great care taken to place the south facing rafters on exact 4' centers, without any cumulative errors. This is most easily achieved by measurement from the same location for all the rafters, rather than by measuring the 4' intervals separately.

Figure 4.1 shows the attic of a Pyramidal Optics Solar System in cross section. The dimensions shown are for the South Carolina townhouse condominium, and will vary in other Pyramidal Optics Solar Systems. The southern rafters are 3' x 8's located on 48" centers while the northern rafters are 2' x 8's on 24" centers, Figure 4.2.

After the rafters have been accurately framed, horizontal solid bridging members are added to define the upper and lower extremities of the solar window. These are 2 x 8's and their accurate placement is as important as the location of the rafters in ensuring the success of waterproofing the solar window. The 2 x 8's must be precisely 16'-0" O.C., and must make an angle of exactly 90^o with the rafters. The upper row should be installed first, with their lower edge touching the ridge beam of the roof. Then the measurement of 16'-0" down the rafter from the centerline of the 2 x 8 made at both the east and the west end of the attic. Connection of these points by a chalk line gives the centerline of the lower 2 x 8's.

Absorber Supports:

Absorber supports fulfill the three functions of acting as a roof brace, providing an attachment surface for the reflector supports, and giving a plane to which the absorbers can be attached. The angle of these members must be measured very accurately, as their placement and the subsequent location of the absorbers has a great deal to do with the success of the energy collection system.

The absorber support can most easily be assembled on the floor of the attic before being lifted into position and nailed. Measurements of both the length and the angles to be cut should be made with care. As shown in Figure 7.2 the absorber support is a 2 x 4 frame "wall", to which is nailed 3/8" sheathing. A top and bottom "rail" of 2 x 3's is then added. These parts serve to provide space under the absorber for insulation as well as support for the absorber itself. When the absorber support has been joined into a single unit, it is raised into position and nailed to the rafters and floor joists. The top rail of the absorber support must be level, to insure that the absorber panels will

be level when they are attached to the rails.

Reflector Supports:

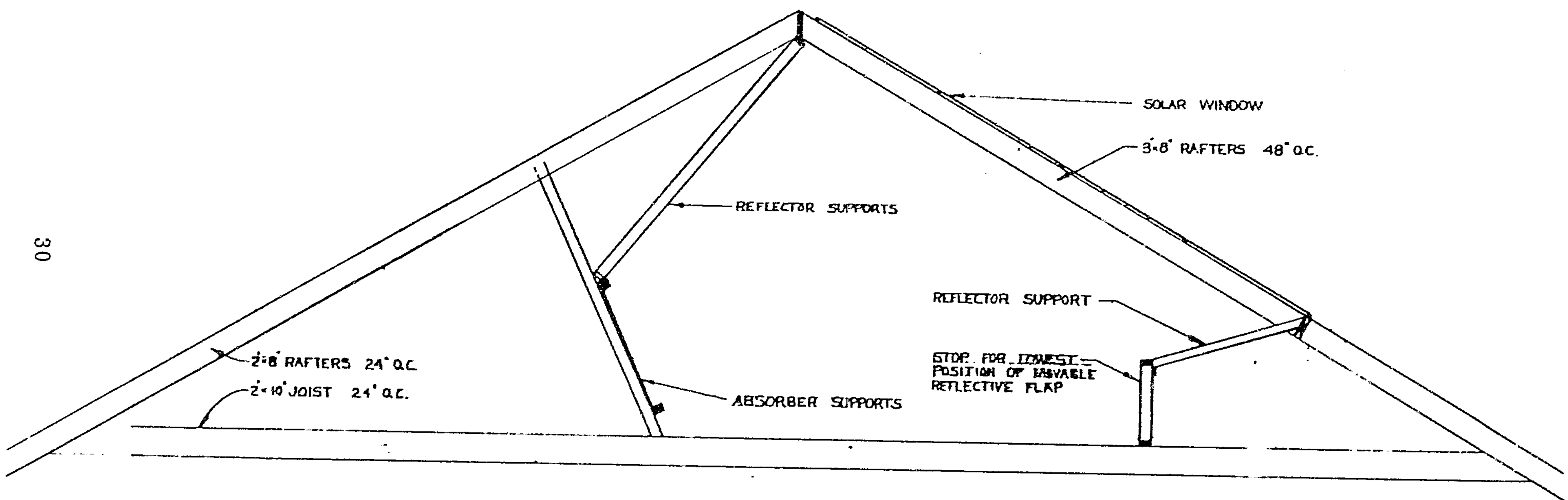
Reflective material covers all of the interior of the attic space which is not occupied by the absorber or solar window. Supports for this material can be seen in Figure 4.1 between the top of the absorber and the ridge of the roof and along the floor of the attic south of the absorber. The reflective panels are supported at 16" intervals to reduce the tendency of the material to sag.

The reflector supports connecting the absorber supports with the ridge of the roof can be assembled on the floor, as was the absorber support. Accuracy is once again very important, to ensure that the completed unit will fit when it is lifted into place, and to permit the system to achieve the efficiency for which it is was designed. 2 x 4's are cut to length and joined on 16' centers by nailing 2 x 4 plates to each end. The completed unit is then lifted into the position shown on Figure 4.1 and nailed to the ridge of the roof and to the absorber support.

Reflector supports on the attic floor serve as attachment points for both fixed and moving reflectors. In the installation pictured, a continuous 2 x 6 was nailed to the rafter brace in such a way that the hinge line of the moving reflector was 2'-4" south of the centerline of the attic and 10" above the floor joists. These dimensions may vary in the projects for which this manual is intended. From the moving flap hinge point to the bottom of the absorbers run additional 2 x 4 framing 16" O.C. for reflective material.

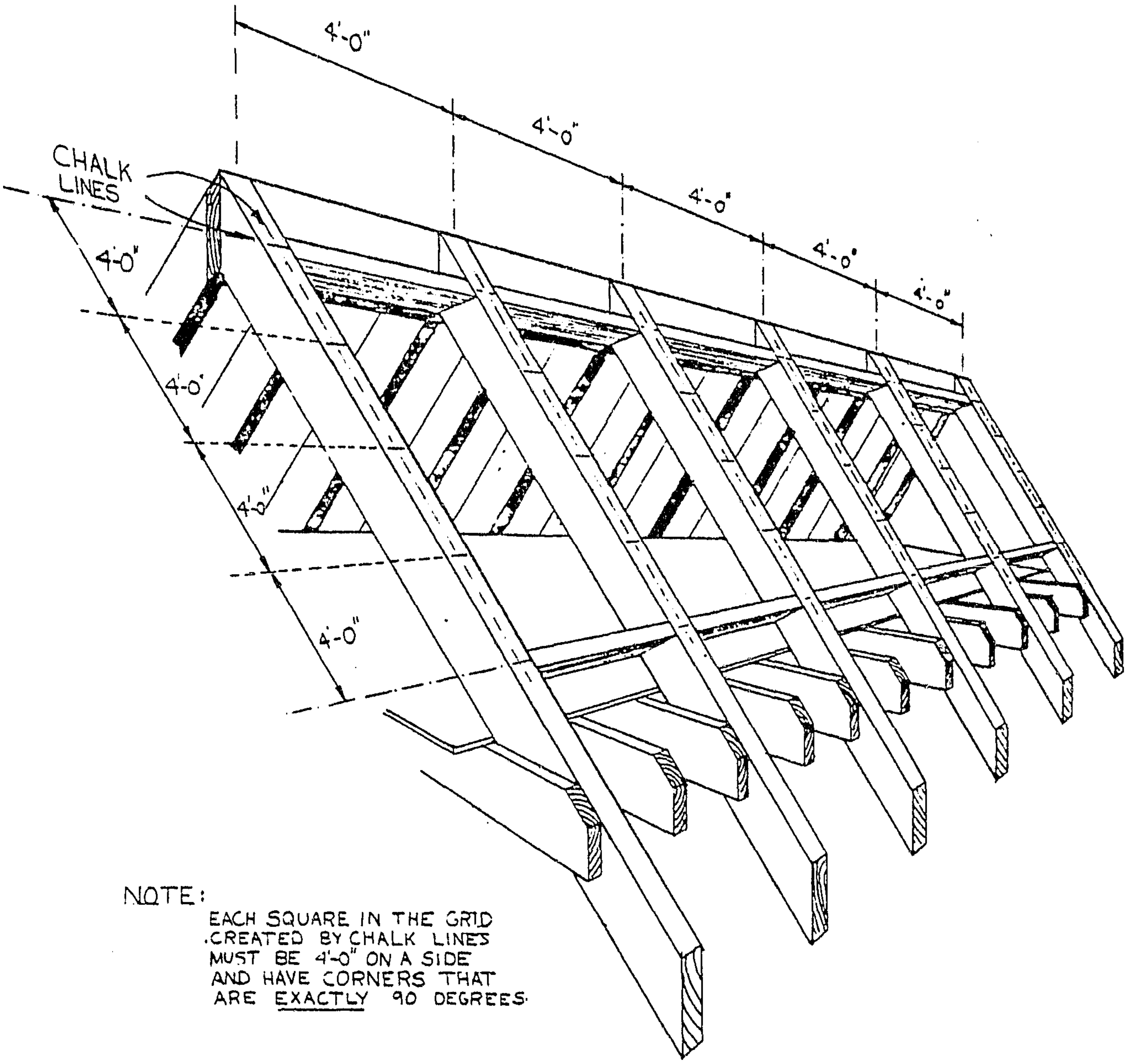
At the southern edge of the attic, supports are built for the attachment of additional fixed reflectors and for the moving reflector to rest on in its lowest position. A sloping platform is fabricated as shown with 2 x 4 lumber 16" O.C.

FIGURE 4.1



ATTIC STRUCTURAL SUPPORTS

FIGURE 4.2



RAFTER SPACING

5.0 Solar Window Glazing System

The glazing system is made up of three components: a neoprene gasket, an aluminum adapter screwed to the wood support members into which the gasket fits, and the plexiglass glazing sheets. The neoprene gasket is a lock strip "zipper" type that was first used 25 years ago at the General Motors technical center. As shown in cross section in Figure 5.1, the gasket is shaped like an "H." The toothed flange of the gasket fits into the adapter reglet. The glass is inserted by lifting the upper lips of the gasket and sliding it in. After the glass is in place, the zipper lock strip is inserted into its cavity locking the glazing in place.

Installation of Glazing System

The "zipper" gasket used to seal the solar skylight requires accurate, careful installation. At NO time during the glazing installation should a screwdriver or other metal tool be used on the gasket material, since doing so might cause a tear which could result in a serious water leak. (Nylon spatulas are provided by the manufacturer to pry the glazing into the gasket.) There are eight assembly steps.

1) Installation begins with the erection of the rafters. These are on 4 foot centers, and must be laid out square. Chalk lines should be used to obtain the required accuracy. It is very important to avoid cumulative measurement errors, so all measurements should be made from a single position. Failure to maintain accuracy within plus or minus ¼" in this step results in the inability to eventually obtain a watertight seal, so precise carpentry is required. Measurement of the diagonals of the skylight is necessary so that a rectangle rather than a parallelogram is obtained.

2) Attachment of the aluminum channel that will hold the gasketing is attached to the rafters, as shown in Figures 5.2 and 5.3. The screw holes should be predrilled in the aluminum. The squares that are laid out on the rafters must have sides that are exactly four feet in length and all intersections must be exactly 90 degrees. A schematic view of one 4' square with the aluminum channel in place is shown in Figure 5.4.

3) The gasket material is unfolded and laid over the aluminum channels that are to receive it. The gasket is then fitted into the channel with a rubber mallet. This step must be done avoiding cumulative bunching of the gasket. Begin pounding in the gasket in the center of each 4' bay and work evenly to each corner. If the gasket comes in sections, joints between gaskets should be caulked as they are installed with caulk described in Step 5.

4) The acrylic glazing is now inserted into the gasketing material. To do this:

a) Peel the protective paper backing from the pane that is to be installed.

b) Liberally lubricate the gasket opening with the jellylike lubricant provided by the gasket manufacturer.

c) Insert the acrylic glazing, beginning with two edges. The gasket is opened with a nylon spatula provided by the manufacturer. Fitting of the final corner requires the most prying, and is impossible if there have been errors in the rafter or channel placement.

5) After the glass is in place, a small bead of caulking compound is inserted under the edge of the gasket at each lower corner. A high grade glazing caulk must be used, such as PTI 707 Architectural sealant, by Protective Treatments, Inc., Dayton, Ohio, Conforming to Federal Specification TTS-001657.

6) The edge flashing is inserted into the perimeter slot provided. This operation can be aided by the liberal application of lubricant on both flashing and slot.

7) Once several columns of glazing are in place, the lock strip that seals the gasket is applied. This material fills the seam on top of the gasket, placing pressure on the gasket lips against the glazing. To install this strip:

a) Lubricate both the slot in the gasket and the locking strip that is to go in it using a pump oil can for the slot and a saturated rag for the strip.

b) Work the strip into position using the special tool supplied by the gasket manufacturer. At intersections of the 4' square panels, one piece of the lock strip must be cut. Which piece is cut does not matter as long as neat butt joints are obtained.

8) At the conclusion of the installation after all dusty work, the plexiglass should be washed. This must be done in such a way that scratching of the glazing is avoided. Use only soft cloths and liberal quantities of water.

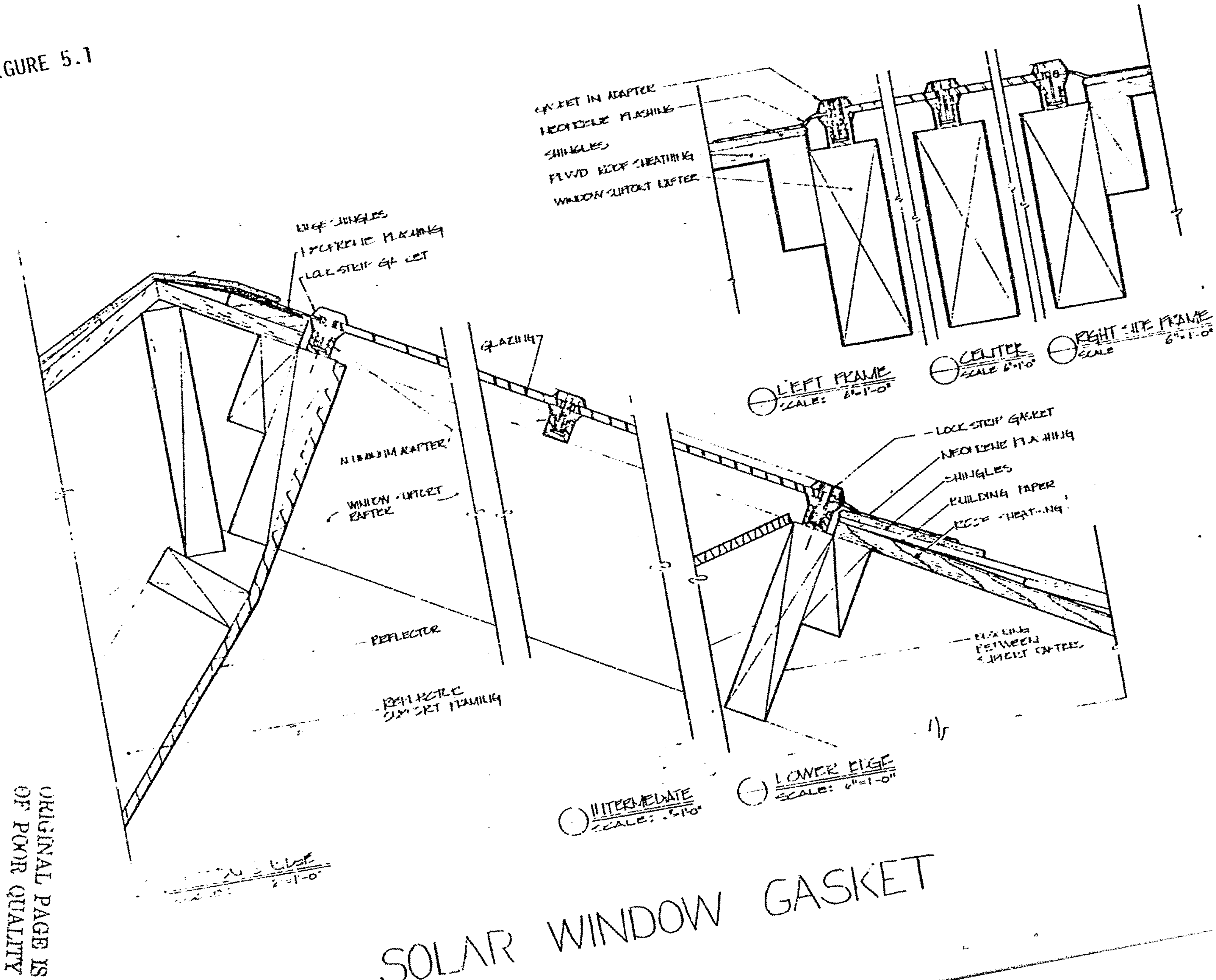
Operation of the Glazing System

The glazing system has no moving parts and operation is automatic.

Maintenance of the Glazing System

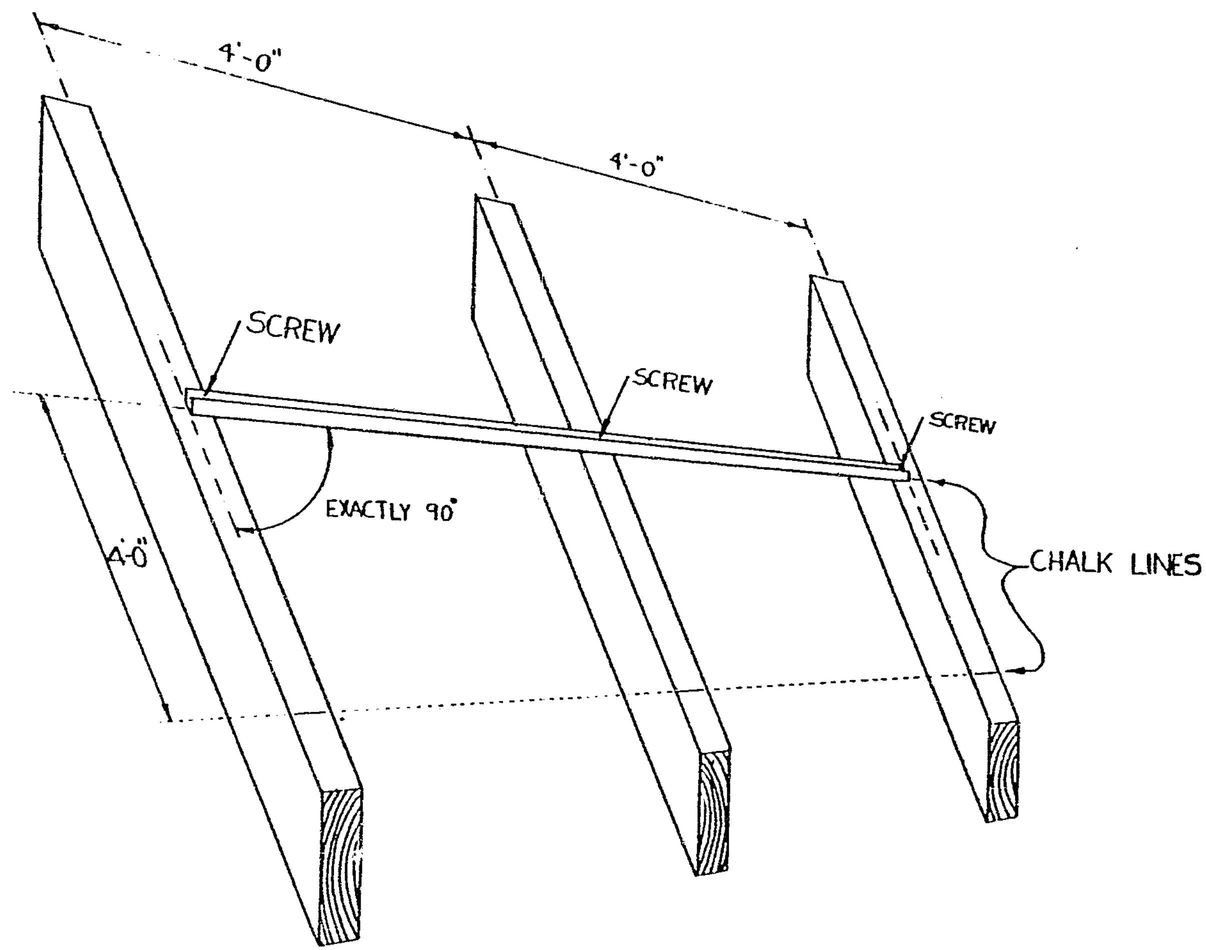
Only minimal maintenance is normally required. The sliding off of rain and snow provides sufficient cleaning action. If exceptionally dirty conditions prevail, cleaning may be done with a soft cloth using plenty of water. Under no circumtances should abrasives be used. These would quickly scratch the glazing surface. Interior cleaning of dust should be done annually with a soft dust cloth.

FIGURE 5.1



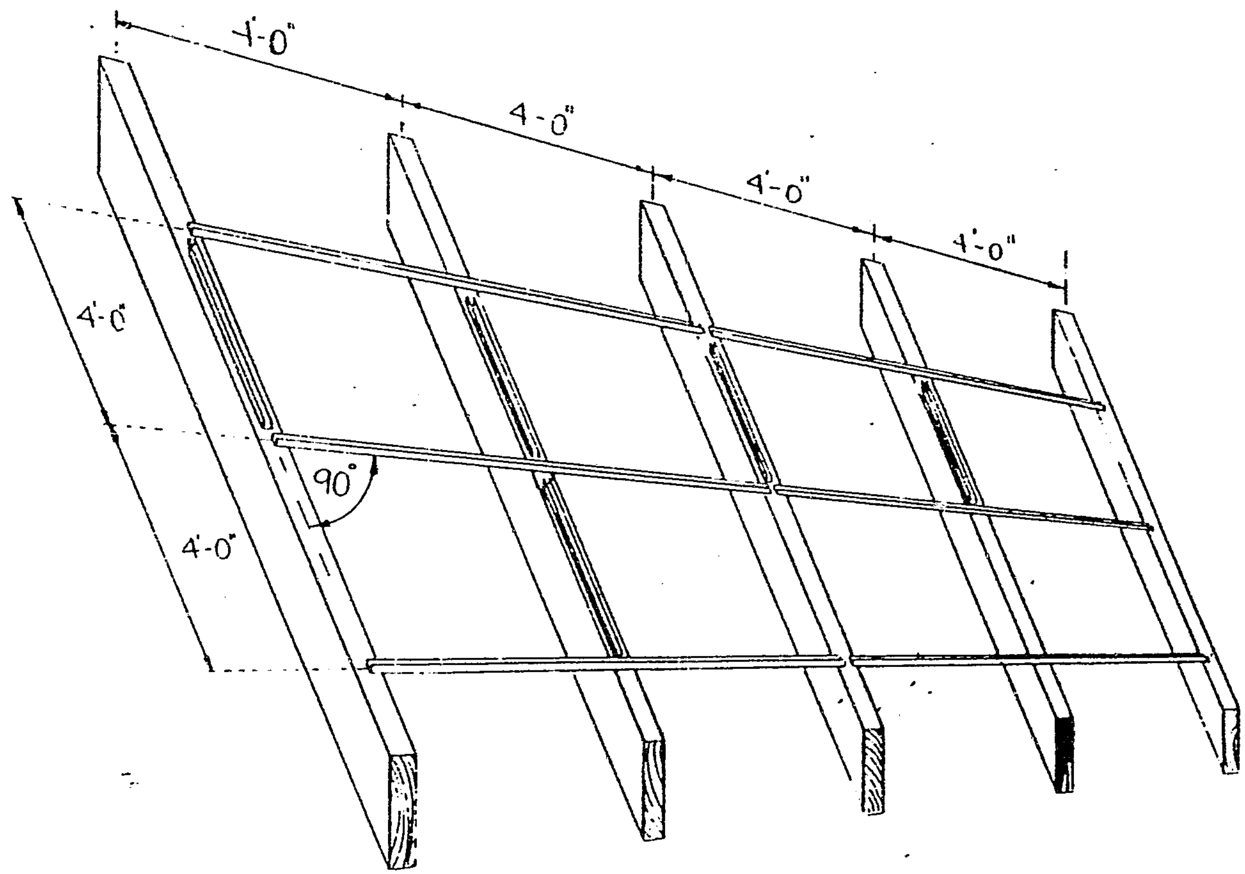
ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 5.2



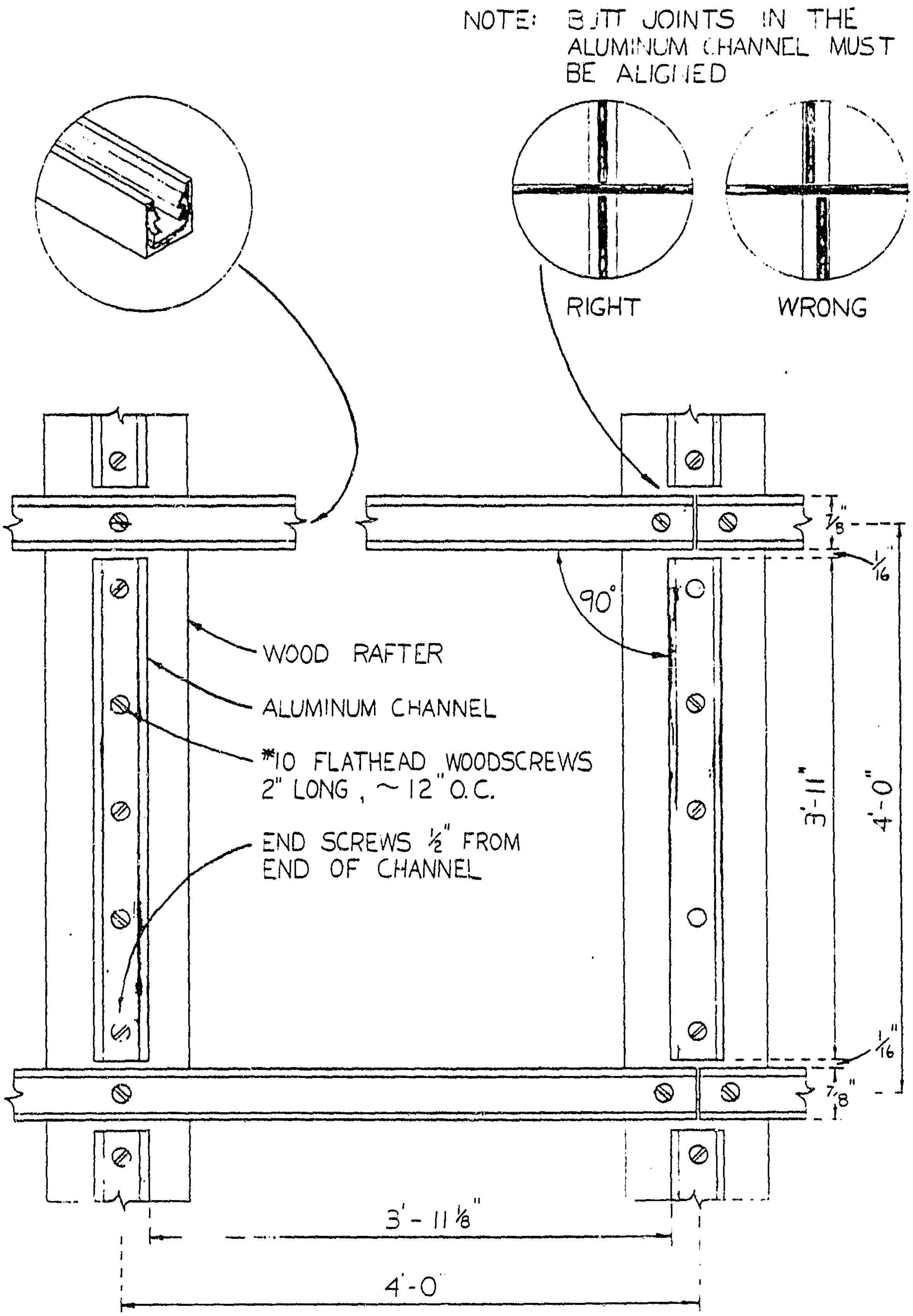
SOLAR APERTURE WITH THE FIRST CHANNEL IN PLACE

FIGURE 5.3



SOLAR APERTURE WITH SLVERAL
SQUARES OF CHANNEL IN PLACE

FIGURE 5.4



SCHEMATIC VIEW OF CHANNEL

6.0 Reflective Mirror System

Installation of the Reflective Mirror System

A. Stationary Mirror System

Installation should be made only after building is completely weather sealed. Prior to installation panels must be stored in a dry location. All but the floor-mounted moving flap are fixed panels. The fixed panels should be handled with care during installation to maintain the mirror finish. The panels can most easily be attached, as shown in Figure 6.1 by use of a staple gun powered by an air compressor which allows the use of coated long leg staples, 3/4" (e.g. Duo-Fast BW6524 with 3/4" No. 6524 CXR staples 8" O.C.). Air pressure should be regulated so that the crown of the staple rests on the surface of the reflector. It should not crush the reflective board. The cutting of the reflective board is a dust-creating process and workers should wear breathing masks.

B. Moving Reflective Mirror

The moving reflector with its "Solar Altitude Compensator" consisting of a winch and timing box, is pictured in Figures 6.2 and 6.3. The assembly steps are described below:

1. Lay out the frame on any large, flat area. Cut the aluminum to size, drill the attachment holes, and mark the mating joints.

2. Carry the parts into the attic, lay them out on the ceiling joists and connect the joints with rivets.

3. Mark the correct locations for hinges. Drill these and install the hinges.

4. Attach the cable to the reflective flap using the "yoke" arrangement shown in Figure 6.2. To do this, attach the pulleys at the locations specified. Then string the cable through the pulleys, attach their ends, and pull on the cable to raise the flap to its highest elevation. Temporarily clamp the cable, holding the flap in this position.

5. Install the gearmotor which is to raise and lower the flap at the approximate location shown in Figure 6.2 by screwing the baseplate to the ceiling joists.

6. Install the cable to the drum of the gearmotor by fitting it through the hole near the shaft on one of the sheaves and applying a cable clamp to prevent it from slipping back. Adjust the length of the cable so that some cable is wrapped on the drum when the flap is at its lowest position.

7. Lay the reflective panels into the moveable frame.

NOTE: The rest of the installation instructions refer to the timing box which together with the gearmotor forms the "Solar Altitude Compensator" (SAC) by which the moving reflector is adjusted. A 115 volt power supply must be provided with ground for the timing box. Wiring from the timing box to the two swtiches that activate the gearmotor is provided with the SAC. The switches are bolted to a mounting plate.

8. Position the timing box and permanently attach to the ceiling joists. This is done with wooden blocks to raise the box to the correct height. The timing box has a moving 4-bar linkage, with links visible on Figures 6.2 and 6.3. The box is in the correct location when the link bolted to the box is horizontal and the end of this link protruding from the box is in line with the hinges of the moving reflector. Block the box to the correct height, nail the blocks to the ceiling joists, and screw the box to the blocks.

9. Join the wires connecting the timing box and the gearmotor in the junction box provided. Match the numbers provided to join the correct wires.

10. Connect the timing box to a grounded 115 volt power supply.

11. Test the Solar Altitude Compensator to ensure that the flap will be moved automatically from its lowest position on December 21 to approximately 42 degrees on June 21. To do this, override the slip clutch and turn the shortest link slowly through one complete circle. One switch and then the other should be activated, and the flap should raise and lower once, simulating the passage of one year. If this test is satisfactory, continue manually adjusting the flap until the angle is correctly set for the current week of the year. Opeartion of the Solar Altitude Compensator now continues automatically.

Operation of the Moving Reflective Mirror

The angular change of the moving reflective mirror is entirely automatic once the mechanism has been correctly installed and tested through its full raising and lowering cycle. The gearmotor will operate momentarily every week or two to keep the flap at an optimum angle.

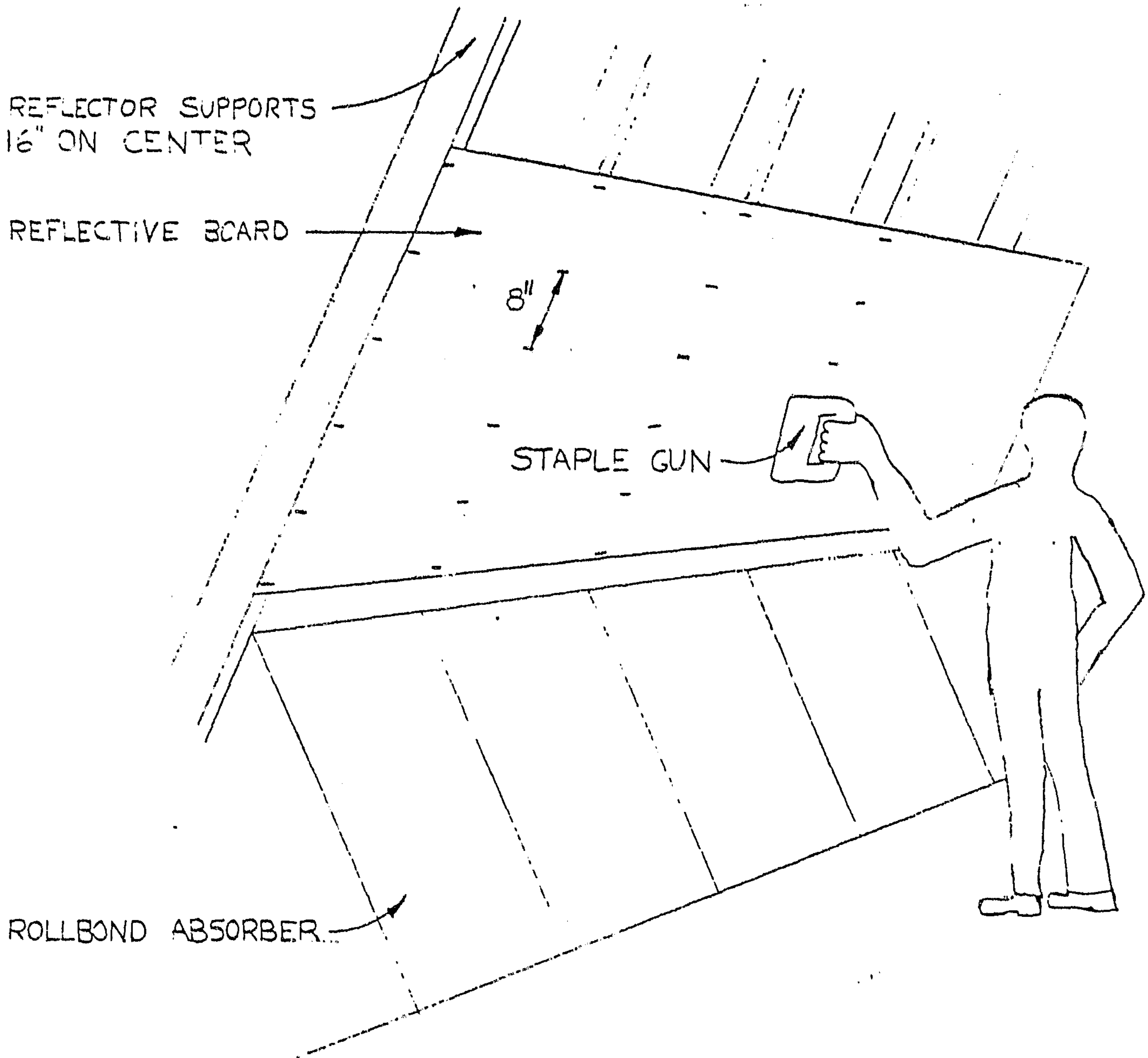
Maintenance of the Moving Reflective Mirror

The reflective panels should be kept free from excessive dust. A soft, nonabrasive dust mop or cloth should be used annually.

Twice a year the flap mechanism should be checked for accurate positioning. Thiscan be most easily done on December 21 when the flap should be in the lowest position, and on June 21 when it should be in the highest position. If an adjustment is required, change the position of the shortest link of the mechanism by manually overriding the slip clutch on the timing box of the SAC. Also, at this inspection, vacuum the ventilation opening in the gearmotor to prevent any accumulation of dust in the windings.

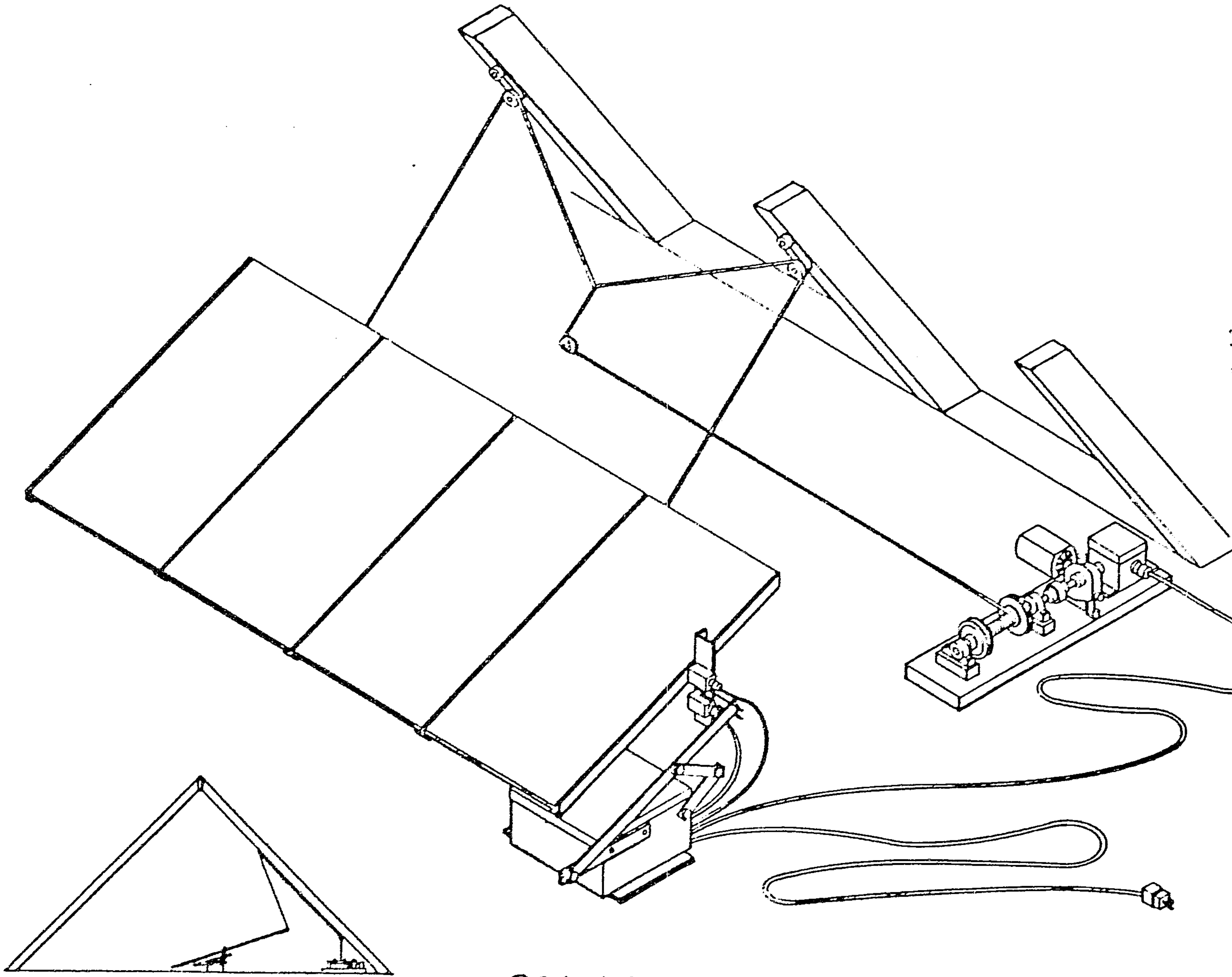
The gearmotor should not require lubrication more frequently than every ten years. Use American Oil Co. Amolith #2EP, Mobile UX-EP2, Gulf Crown #EP2, Alvania #EP2, or Multifax #EP2. Because of the infrequent motion of the flap , brushes on the gearmotor should not need changing during the life of the installation.

FIGURE 6.1



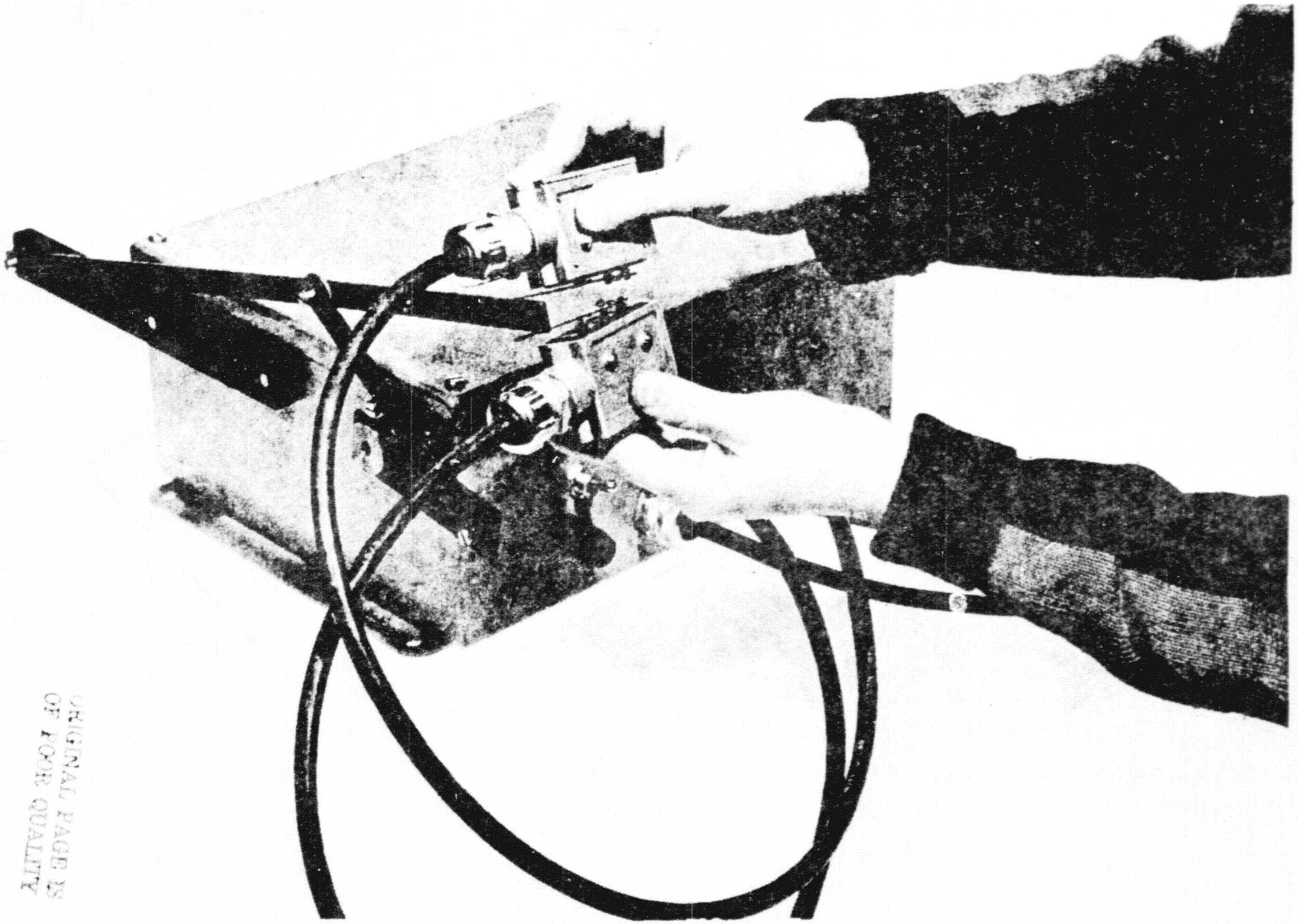
ATTACHMENT OF REFLECTIVE PANELS

FIGURE 6.2



SOLAR ALTITUDE COMPENSATOR

FIGURE 6.3



ORIGINAL PAGE IS
OF POOR QUALITY

TIMING BOX OF THE SOLAR ALTITUDE COMPENSATOR

7.0 Absorber Plate System

The absorber panels used in the Wormser Scientific Pyramidal Optics Solar System are "Solar Bond" copper absorbers, made by the Olin Brass Company of East Alton, Ill. and illustrated in Figure 7.1. The panels are 34" x 47" x .040" thick and provide integral tubes and headers within the copper plate. These panels are produced using a patented "RollBond" process, in which two sheets of copper are metallurgically bonded together and then expanded in selected unbonded areas to form integral flow passages. Tests of Olin Brass have demonstrated that "Solar Bond" panels offer a greater efficiency than those of other manufacturers when absorbers were compared in identical housings. The close tube spacing is largely responsible for this advantage. The 33 parallel flow tubes provide a comparatively short distance for the flow of heat before it reaches a flow passage. The use of integral headers and the absence of brazed, soldered, or adhesive surfaces within the absorber are also benefits of this design.

During the manufacturing, the absorber panel surface is selectively blackened by the deposition of a Black Chrome. This surface increases the heat absorbing ability of the panel. It has an absorbtivity of 0.9 or better for absorbing sunlight and emissivity of less than 0.1 for emitting long wavelength infrared radiation. It is a relatively fragile coating. When the absorbers are received at the job site, they should be stored indoors in a clean, dry place. Their installation should occur only after the building is weather-tight and must be done with care to avoid scratching or abrading the surface.

Installation of the Absorber Plates

The assembly of the absorber plate system is illustrated in Figure 7.2, which is a cut-away view of the components.

1. Plywood Backing

This serves as a support for the insulation which must cover the rear surface of the absorber to prevent unnecessary heat loss. The nailing of the plywood to the rafter brace is described in Chapter 4 of this manual.

2. 2 x 4 Rails

These members (which may be 2 x 3's or 2 x 4's) provide a surface for the attachment of the absorbers. They are nailed to the angled braces through the plywood, along the full length of the absorber array, as described in Chapter 4.0 of this manual.

3. Insulation

Insulation of the back side of the absorber (the side not exposed to the sun) is necessary to prevent heat being lost to the air of the attic. Two materials are specified. First, a 1" thick rigid fiberglass insulation is glued to the 2 x 3 rails to isolate the absorber surface from the wood.

(The use of nails would provide a thermal short-circuit, partially defeating the purpose of the insulation.) Second, unfaced (no paper or conbustible material can be in the absorber area) batts of 6" thick fiberglass insulation are cut to fit and laid into the space between the top and bottom rails.

4. Absorbers

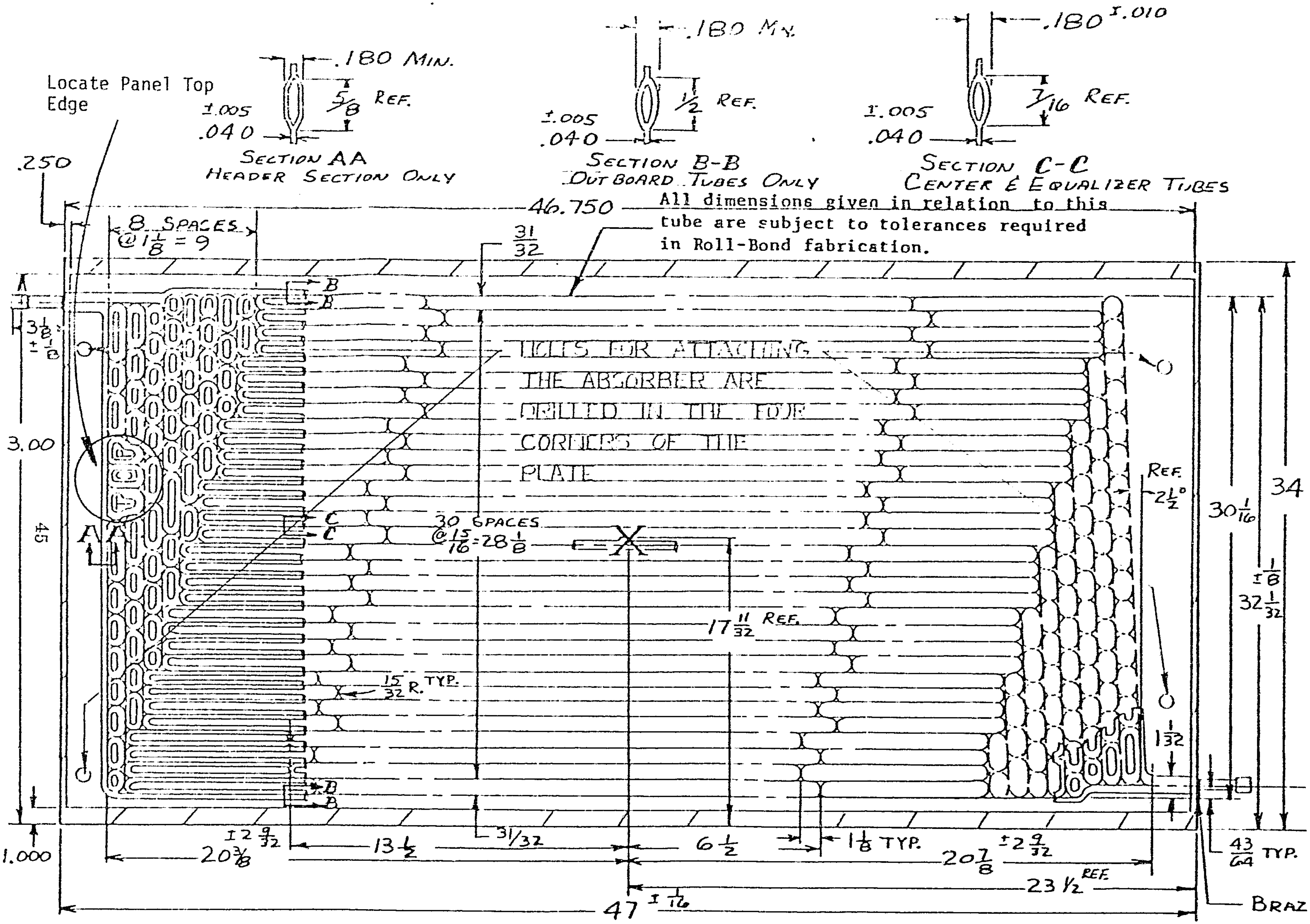
After uncrating, the absorbers should be drilled for their attachment to the rails by screws, at the locations shown on Figure 7.1. This must be done with great care to avoid any puncture of a flow passage. The holes should be at least 2 drill sizes larger than the #8 screws that will be used to attach the absorbers to allow room for thermal expansion. Note that the word "Top" is formed into the flow tubes at one end of each absorber to eliminate any possibility of installing an absorber upside down. The absorber at one end of the array is aligned on the rails, pilot holes are drilled, and the absorber is attached with #8 round head wood screws, 2½" long with a 1" washer under its head. The screws should be drawn down firmly but not tight enough to deflect the surface of the copper plate. The fiberglass insulation underneath should be compressed no more than ½". The second absorber is aligned next to the first with a 1/8" gap between the two for thermal expansion, and the process repeated. This procedure is continued across the array until the final absorber is secured.

Absorber Plate Operation

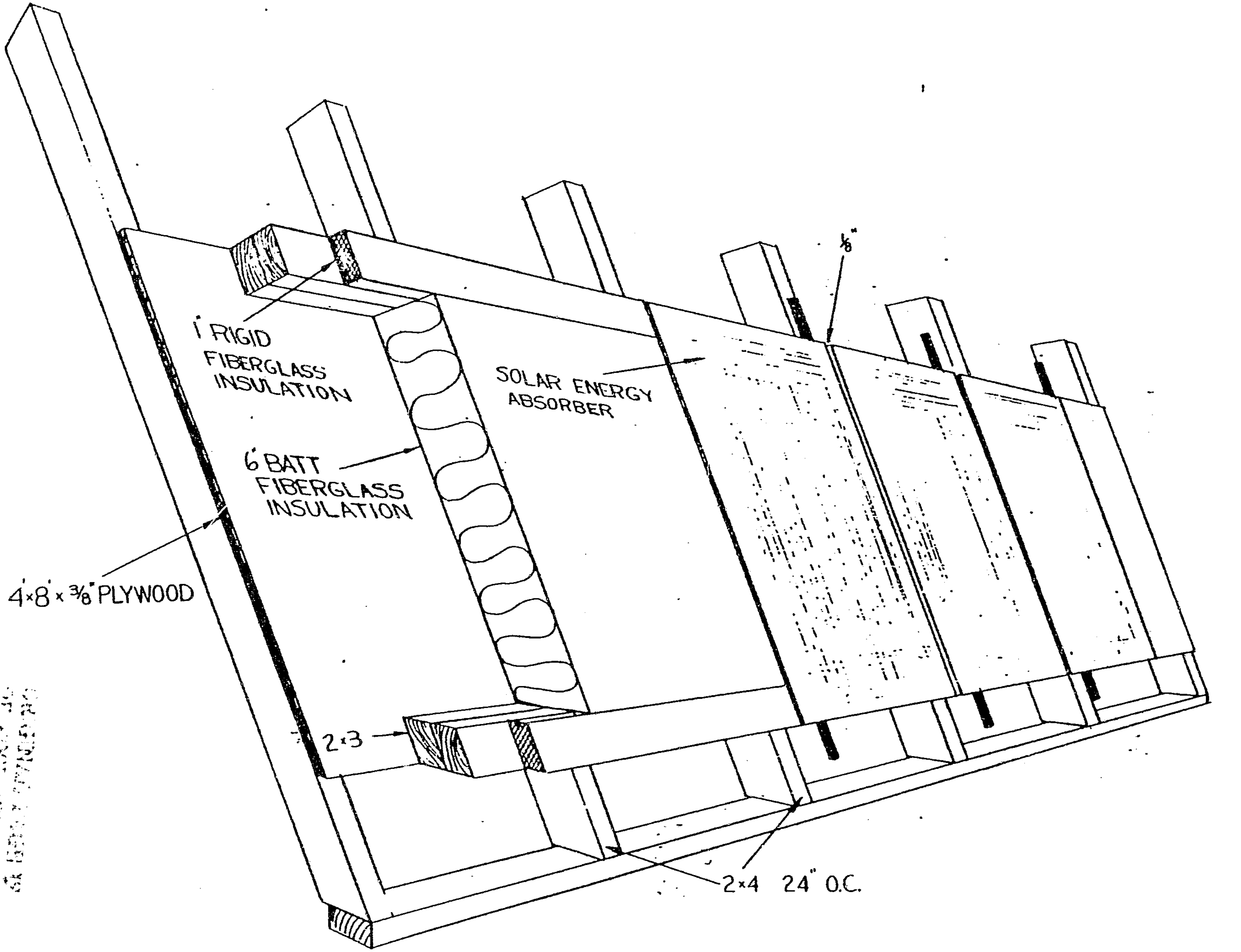
During operation water flows from the 1" bottom manifold tube through the absorber plate fluid passages carrying away accumulated solar energy into the top 1" manifold tubes as described in Chapter 1. This action is completely automatic requiring no attention.

Maintenance of Absorber Plate

Only an annual dusting is required to keep the absorber plates in top operating condition. This should be done with a soft cloth to avoid scratching the special absorber surface. No liquid cleaners should be used.



COPPER ROLLBOND ABSORBER



CUT-AWAY VIEW OF THE ABSORBER PLATE SYSTEM

8.0 Collector Piping System

The plumbing involved in the Pyramidal Optics Solar System is quite straightforward. There are few, if any, operations that would not be encountered on a non-solar job. The principal cautions that must be observed are the use of 95/5 solder throughout, and the careful sloping of all pipes so that the system will drain down when the pumps are off. Pitching the pipes also serves to prevent the reduction in flow that results when air pockets partially block the pipe. The collector piping system is pictured in Figure 8.1, a flow schematic of a Pyramidal Optics collector system designed for a single family home. The slant of the manifold piping can be seen, as well as the location of balance valves. These are included to permit the balancing of flow through all sections of the absorber, a step which is necessary to bring the system performance to an optimum after start-up.

Installation

The first step in the installation of the collector piping system is the roughing in of the lines running between basement and attic. Before the joints are sweated, it may be possible to slip uncut lengths of insulation onto the pipe. This eliminates the necessity of slitting and gluing of the insulation, resulting in faster installation and fewer heat leaks. When the joints are sweated, the insulation must be held away from the hot joint by clamps. Because a considerable number of pipes are stubbed into the mechanical room, each one should be labeled as it is installed.

In the attic, the absorbers should be already in place, installed according to the instructions in Chapter 7. The connection of the external manifolds to the collectors begins with the snapping of chalk lines above and below the absorbers. These will help to install the manifolds at the correct slope, ¼" per foot above the collectors and 1/8" per foot below them. Nipples are then cut and attached to the inlet and outlet of each absorber with the free end extending to the chalk line. As shown on Figure 8.1, the first collector to receive water from the pump should have the longest bottom nipple and the shortest top nipple. Tees and horizontal lengths of pipe are then cut to connect the nipples. These pieces are sweated into place across the bottom and top of the absorbers, completing the manifolds. Four additional fittings are inserted in the lines. These are an automatic air vent and a vacuum breaker at the high point of the system (after the last absorber panel and just before the return line begins its descent to the tank) and two ball valves which are located 1/3 of the distance from each end of the absorber array and whose purpose is to balance the flow to each.

The fittings that are included in the piping to the thermal storage tank are shown in Figure 8.1. These include a balance valve, thermometer, circulating pump, strainer, sight glass, gate valves, and numerous unions. As in the attic, the plumbing must be installed so that air is never trapped in the lines. Where pipe size changes are made, an eccentric fitting should be used, mounted with the flat side up. The pump must be installed below the water level of the tank. This is necessary to ensure that the pump operates with a positive suction head, as it must in a non-pressurized system. Pipe and fittings on the suction side of the pump should be

installed to minimize friction and turbulence, both of which adversely affect the performance of the pump. The supply from the tank should be near the bottom and the return near the top of the tank to aid in setting up beneficial thermal stratification. For a discussion of how to penetrate the walls of the tank and obtain a watertight seal, see Chapter 3.

When the plumbing has been completed, the collector piping system must be tested for leaks. This is done by pressurizing the system (without the air vent) with air at 60 PSI for 24 hours. Any drop in pressure during this time indicates the presence of a leak, which must be located and fixed.

When all leaks are corrected, the tank filled, and the pump correctly connected to the electrical control system (See Chapter 12), the system should be tested. This is done by priming the pump according to the manufacturer's instructions, operating the pump, and observing that the system fills with and circulates water. Air bubbles should have stopped entering the tank through the return line within five minutes after start-up. When air bubbles have all been pushed out the automatic air vent or through the line back into the tank, the flow should be set at the maximum rate attainable at the balance valve downstream of the pump. This flow rate should be checked with a meter, and will probably be the greatest when the balance valve is wide open. (In systems that impose low piping and vertical "heads" upon the pump the maximum flow rate has been found to be some intermediate setting of the balance valve.)

The ball valves on the upper and lower manifolds of the collectors should be adjusted to provide equal flow through the left, center, and right third of the array. This adjustment is made by comparing the temperature of the different sections of the absorber when the pump is operating and when sunlight is hitting the absorbers. A cool absorber indicates a high flow rate while a hot absorber means that little water is passing through. The flow is balanced by comparing the temperatures (measured by a handheld thermometer) in each third of the array and changing one or both ball valves to eliminate differences. After the setting on a valve is changed, several minutes must be allowed for the temperature to equilibrate at the new flow rate before it is measured.

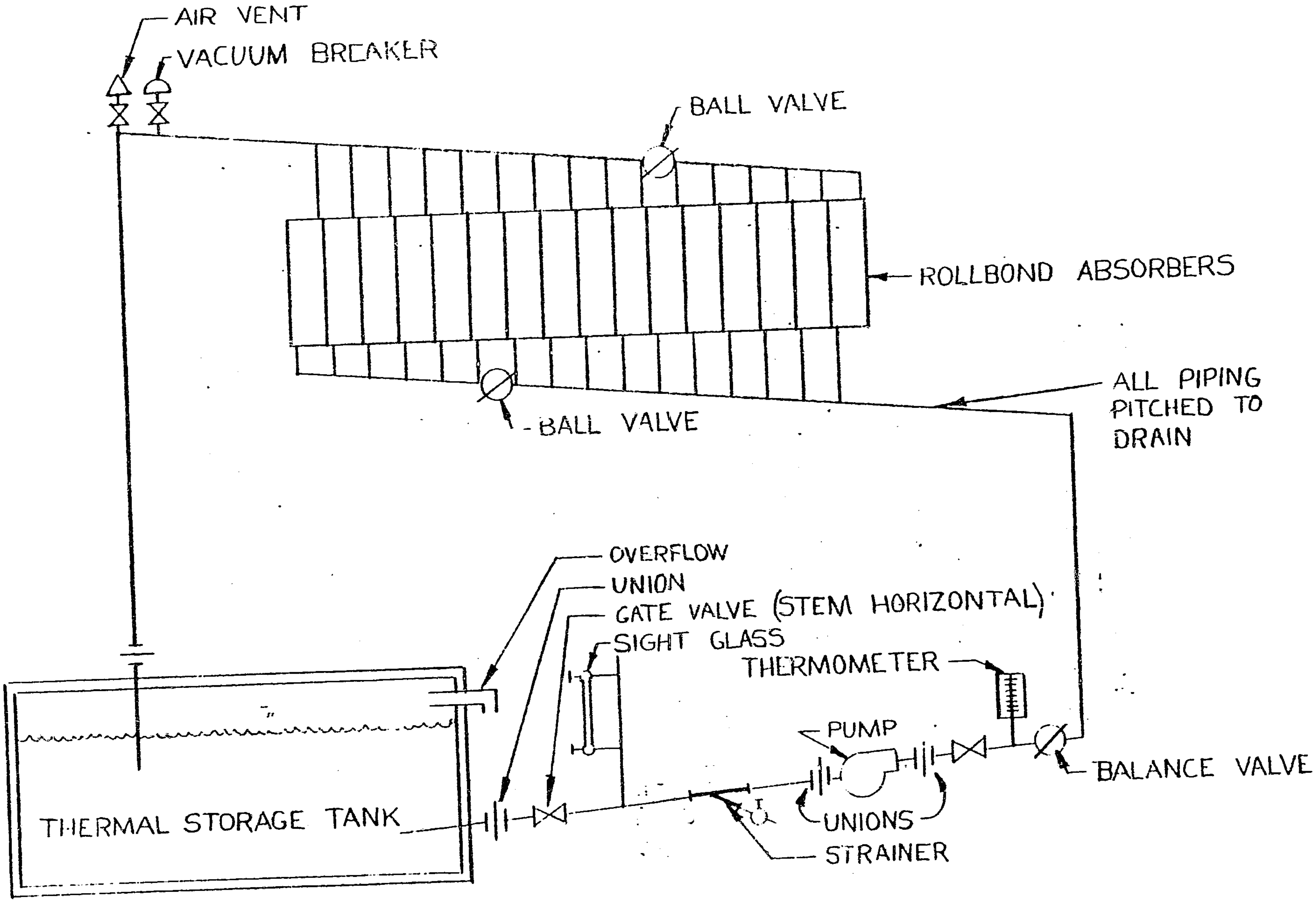
When the overall flow rate from the pump has been set to a maximum in the mechanical room and the flow through the absorbers balanced by the adjustment of ball valves in the attic, the collector piping system is installed and operational. A final check should be that the automatic air vent, providing drain-down freeze protection, is functioning properly. Air rushing out of this unit should be audible when the pump is turned on and air moving in should be heard when the pump is shut off and the drain-down begins.

Operation

The pump operates to remove captured solar energy whenever the differential controller indicates a sufficient temperature difference between storage tank and absorber. The operation of the sight glass, air vent, and piping is automatic.

Maintenance

The ball bearings of the circulating pump are permanently sealed, and require no lubrication. The shaft seal of the pump is lubricated and cooled by the water being pumped. Beyond a periodic inspection of the collector air vent to ensure that it continues to function, the only maintenance required in the collector piping is the cleaning of the strainer in the line upstream of the pump. This should be done after installation testing, then every month for the first three months of operation. After that, cleaning every six months is adequate. If the sight glass should become clouded so that reading the water level becomes difficult, it should be removed and cleaned.



COLLECTOR PIPING SCHEMATIC

9.0 Domestic Hot Water System

The domestic hot water system employed with the Pyramidal Optics Solar System is shown in Figure 9.1. It is a preheat system using the heat contained in the solar storage tank to warm the domestic hot water. When the storage tank is cool, the preheating is supplemented by electric resistance heating which brings the hot water to the desired use temperature . Heat is transferred from the main storage tank to the domestic water tank by means of a closed loop consisting of two heat exchangers connected by copper pipe. One is located in the solar storage tank and the other in the domestic hot water tank. The heat transfer fluid is pure water, which is circulated by a pump to which power is supplied by a differential controller whenever the solar storage tank is 15^0 or warmer than the DHW tank.

Installation

The domestic hot water system pictured in Figure 9.1 is typical of the systems used with the Pyramidal Optics Solar System, but should be used as a reference only, with installation made according to the specifications shown in the working drawings prepared for the individual project. Plumbing of the domestic hot water preheat system can either precede or follow the plumbing of the domestic hot water distribution network throughout the building. Plumbing the heat exchanger in the domestic hot water tank consists of attaching to the external fittings on the tank, as the heat exchanger is supplied integral to the tank.

The heat exchanger in the solar storage tank is to be made of copper piping, either straight lengths or coils of twisted copper tube ("Turbotec") tubing. These must be suspended in the tank and firmly anchored just below the future water level with brass or non-metallic hardware. The circulator should be installed so as to pump out of the expansion tank. The expansion tank, unions, gate valves, pressure gauge, and drain and fill connections should be plumbed in accordance with good plumbing practice. A hand air vent is added at the system high point to permit the removal of air trapped inside the system at the time of installation. As in the installation of the collector piping system, the installation of uncut lengths of pipe insulation before the joints are sweated may yield dividends both in time savings and in the "tightness" of the insulation. When the system is complete, it should be charged with water to a pressure of 20 PSI. The differential controller is then installed. Its two sensors are located with one in the solar storage tank and the other in the domestic hot water tank. See the chapter on controls for detailed information.

Operation

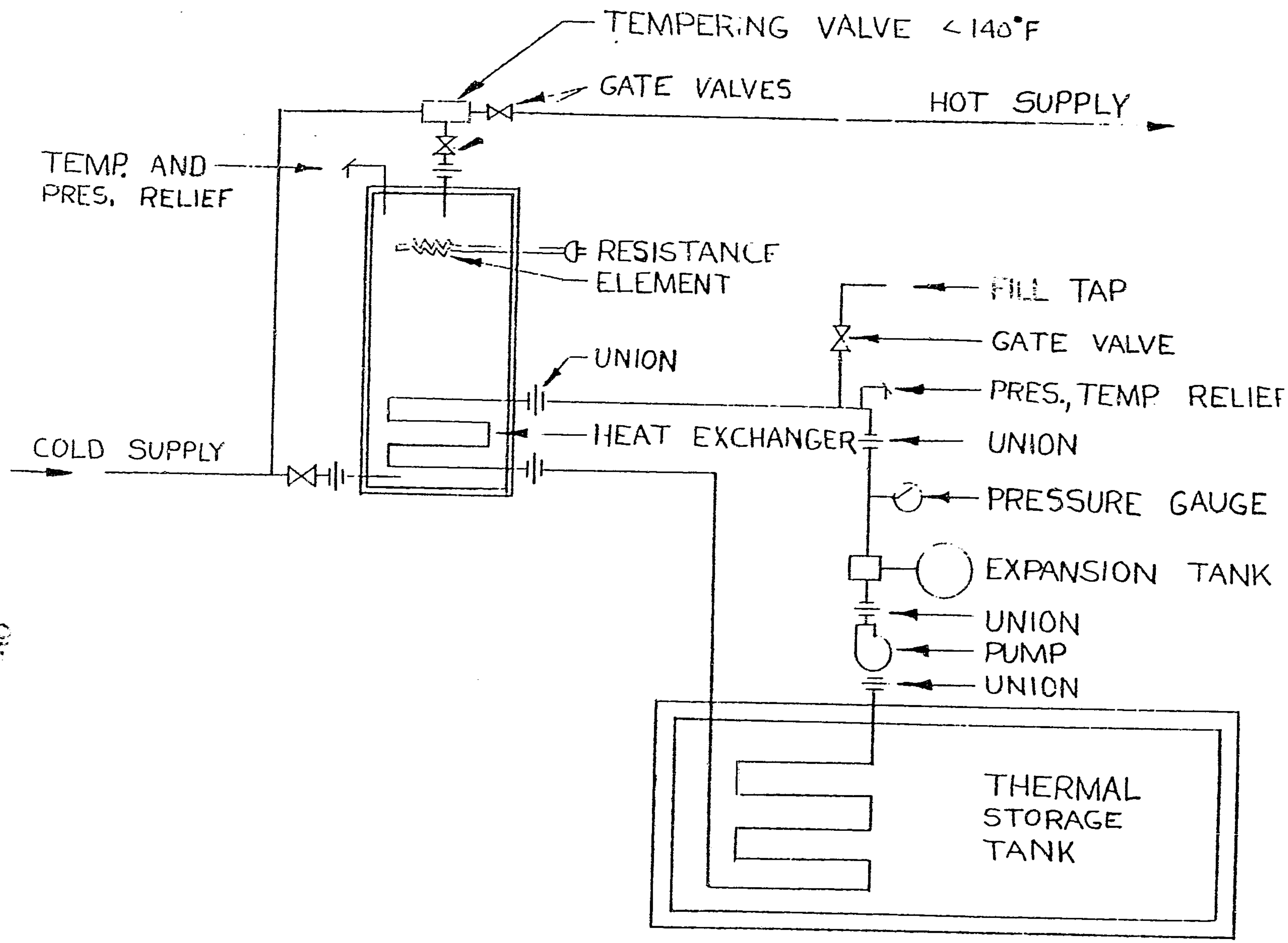
The preheat coil is located in the bottom of the DHW tank while the electric booster element is near the top of the tank, adjacent to the pipe supplying hot water to the home. Thermal stratification in the tank tends to prevent the wasteful use of electric booster heating, since only the top portion of the tank is heated electrically. The preheat coil located in the bottom of the DHW tank, near the incoming cold water inlet, adds whatever energy is available through heating water near the bottom of the DHW tank to the temperature

of the solar storage tank. The heated water in the DHW tank rises, and its temperature is augmented, if necessary, by energy from the electric element.

Whenever the solar storage tank is 15 degrees warmer than the water at the bottom of the domestic water tank, circulation is called for by the differential controller, which activates the 1/20 H.P. centrifugal pump. This circulation continues until the domestic hot water tank is warmed to within 6 degrees of the temperature in the solar storage tank, whereupon circulation ceases. (Trying to bring the two temperatures into exact agreement is difficult and wasteful of pump energy; the 6 degrees was chosen as a differential at which the energy used to run the pump was small in comparison to the amount of preheating obtained.)

Maintenance

If testing of the local water shows a high mineral content the use of deionized water in the storage tank and domestic hot water preheating coil will greatly lengthen the life of these systems. Incoming water of high mineral content can be modified by use of an ion exchange column. The only maintenance that is required is the periodic checking of the system pressure and water level.



DOMESTIC HOT WATER SCHEMATIC

10.0 Solar Auxiliary Unit

The Solar Auxiliary Unit is a self-contained, factory assembled unit. Each unit has been inspected and operationally run tested at the factory by the manufacturer, Friedrich Air Conditioning and Refrigeration Company. The unit has been packaged to arrive in good condition, however, mishandling in transit can cause damage.

Inspection and Handling

1. Inspect outside of shipping cartons for damage.

2. Remove unit from carton and inspect for exterior damage.

3. Remove control equipment panel and inspect for interior damage.

4. Immediately contact last shipping carrier if any damage is noted.

The principle of operation of the water to air heat pump is that heat is rejected to the water from the air to be conditioned (cooled) on cooling cycle and heat is gained from the water by the air to be conditioned (heated) on heating cycle. Dehumidification is also achieved on the cooling cycle by removal of moisture from the air in the form of condensate. The medium of heat transference is the refrigerant. Basic components used in the system are the compressor, co-axial heat exchanger, and a finned coil heat exchanger. The system reverts from cooling to heating cycles by means of a reversing valve. (See Figures 10.1 and 10.2).

A remote thermostat signals the unit to operate on cooling or heating cycle. When the present comfort level is achieved the unit will turn off automatically

The heat pump requires only electrical power of the proper voltage and an adequate supply of water in the range of 40 degrees F to 95 degrees F. A drain for wasting the condensate water is required. Duct work to supply air to be conditioned and return conditioned air is provided by the installer.

The direct solar coil for the Solar Auxiliary Unit is built into the machine. It is a heat exchange coil through which water from the thermal storage tank is pumped whenever the house calls for heat and the temperature of the tank is above 80°F. Air is passed over the coil by the blower of the Solar Auxiliary Unit. Heat is picked up by the air, which then carries the heat throughout the dwelling.

The electric duct heater, also built into the Solar Auxiliary Unit, is a backup heat source for those rare periods when the system malfunctions or the water in the storage tank is below 40°F. Its operation is governed by the electronic control system, described in Chapter 12.

Installation

Typical installation of the 'vertical' models is illustrated in the following diagrams:

Figure 10.3 - Unit in a closet installation

Figure 10.4 - Installation in a utility room or garage

Typical installations of the 'horizontal' models is illustrated in the following diagrams:

Figure 10.5 - Unit on floor, attic, or closet installation

Figure 10.6 - Ceiling mounted installation

For acceptable operation of the Solar Auxiliary Unit, particular care in location, setting and connecting the machine must be exercised. The unit should be installed to provide space for removal of access panels for servicing. The installation should prevent the transmission of noise and vibration to the building structure, ducts, and piping.

It is recommended that vibration eliminator pads be installed at the base of each corner of the unit. The compressor is internally sprung and bolted to the base with special isolation mounts. After installation of the unit, the hold down nuts should be loosened so that the compressor is floating free.

Flexible connections should be inserted between the unit and the duct work.

Water

It is important to have water with enough pressure and purity to insure the proper flow for the unit and prevent scaling which impedes heat transfer and reduces efficiency. When a device is installed to regulate the water flow rate, it should be installed on the leaving water line.

In some cases, water does not harm coils, in others the coils require frequent descaling with chemical descaler. Further, experience has shown that there are several types of deposits that could scale the coils and that no single method has proven effective to combat these several varities. We find that local dealers and service-men, by experience, usually have the best de-scaling methods for deposits that are typical to an area. Should the condenser become contaminated with dirt and scaling as a result of bad water, the condensers will have to be back flushed and cleaned with a chemical that will remove the scale.

The water and condensate lines should be attached by means of flexible connections or suitable hose. Recommended water piping to the unit is shown in Figure 10.7.

Balancing valves installed in the supply water line to the unit will allow for the adjustment of proper flow, and shut-off valves provide a means of water shut-off should it be necessary for servicing the unit.

All units must be trapped. A three or four inch trap should be installed in the condensate drain line as close to the unit as possible. The top of the trap should be below the connection to the unit to prevent the condensate from over-flowing the drain pan.

Successful operation of the heat pump depends on sufficient pressure and adequate quantity of water to the unit. Undersized pipes will result in in-sufficient flow rates, large power consumption,

and reduced capacity of the unit. It will result in high head pressures in summer and possible freezing of the water in the heat exchanger during winter operation.

Water flow rates for efficient operation are listed in the engineering data sheets. The water temperature to the unit must be between 40°F minimum and 95°F maximum. The unit will not operate efficiently at water temperatures outside of this range and damage to the unit may result.

The supply water must be clean, free of sand and solid foreign matter. Also, the supply water must be free of air. Air in the system may set up an oxidation process and create an undesirable scaling condition, in addition to the possible reduction in flow rates.

Supply water must be connected to the condenser to provide a counter flow to the refrigerant in the cooling cycle. Inlet or supply connection is on the bottom, the outlet or discharge connection is on the top of the condenser. These features are shown in Figures 10.8 and 10.9.

No galvanized pipe or galvanized pipe fittings are recommended for use with these units due to possible electrolysis. The water treatment system should be operational with initial water flow.

NOTE: Operation of Climate Master units lacking proper condenser water flow due to valving or improper pump operation is hazardous to the CM units and voids the warranty.

Electrical

Power wiring to the heat pump should be in conformance with applicable codes and connected as shown on the wiring diagram furnished with the unit; an example of this is given in Figure 10.10. No starters are required. The use of flexible conduit in making the electrical connections is recommended.

Each heat pump is furnished for a rated voltage frequency and phase marked on the data plate. For units with a name plate marking of 208/320 Volts, the permissible operating voltage range is 197-253 volts. For units with other voltage markings the operating range must be within plus or minus 10%.

The wiring diagram and nameplate data indicates the dual element fuse size or circuit breaker size for each compressor circuit. Make certain that the unit is adequately grounded.

For 208 Volt operation make the necessary change in transformer wiring as shown on the wiring diagram.

Low voltage wiring between the terminal board in the unit control panel and the wall thermostat should be made in conformance with applicable codes. Color coded low voltage cable is recommended to simplify wiring between the thermostat and unit.

Line voltage and low voltage wiring is illustrated in Figure 10.11.

Duct Work

All duct work must be insulated and have an adequate

vapor seal. This is particularly important where the duct is exposed to very humid conditions such as an attic, vented crawl space, unconditioned basement or utility room. The vapor seal prevents condensation of moisture in the insulating material and subsequent loss of insulating valve.

Noise level can be reduced by use of flexible connections in the duct system near the outlet of the blower.

Refrigerant Lines

Model	Line Size [Up to 25ft]* Suction Line	Liquid Line
22	5/8	1/4
27	5/8	1/4
42	7/8	3/8
52	7/8	1/2
62	7/8	1/2

* For refrigernat lines in excess of 35ft. consult your manufacturers' representative.

Interconnecting refrigerant lines should be insulated and joints should be brazed with an alloy containing at least 15% silver.

OPERATING PRESSURES AND TEMPERATURES

Prior to charging the system the following steps are recommended:

1. Pressure test with dry nitrogen. Locate and repair all leaks.

2. Charge with several ounces of Refrigerant 22.

3. Use a good vacuum pump and evacuate the system to 500 microns vacuum or equivalent (29.9 inches of mercury vacuum).

4. Charge the unit with quantity of ounces of Refrigerant 22 as specified on the dataplate. Do NOT attempt to charge the unit by running the machine and measuring the ampere draw to full load conditions.

There are cases when a particular system will have to be charged in accordance with pressures.

Use Superheat Method When Unit is in Cooling Mode		Use Liquid Pressure when Unit is in Heating Mode			
Ambient [for superheat]	105	95	85	75	65
Superheat	5-10°F	10-20°	20-30°	25-35°	30-40°
Ambient [liquid press.]	55	45	35	25	15
Liquid Pres. Model 22	255	240	230	210	190
Liquid Pres. Model 33	265	255	235	215	190
Liquid Pres. Model 42	270	260	245	230	210
Liquid Pres. Model 52	255	245	225	210	195
Liquid Pres. Model 62	265	255	235	220	205

Heating Cycle: Range of Approximate Operating Pressures (PSIG)*

Air in °F	Water Temperatures °F Entering	°F Leaving	Discharge Pressure (PSIG)
	60	53	210-230
70	70	63	240-260
	80	73	280-300
	60	53	230-250
75	70	63	250-270
	80	73	290-320

*Variances from these operating pressures will occur from machine to machine and model to model.

For abnormal pressures, see the trouble shooting chart.

A machine that is normally operating well on cooling cycle will have a warm (to the touch) compressor dome and cool crankcase at the suction port. If the crankcase and dome are very hot (to the touch) there is an indication of less charge. On the contrary, if the crankcase and dome are very cold or frosting the unit is likely to be overcharged.

CHECK, START-UP, AND TEST

After the unit has been installed, wired, piped and ducted the unit is ready to be checked, tested, and balanced for continuous operation.

Before starting the unit, check the following:

1. Proper voltage to unit
2. Correct fuse sizes
3. Tight electrical connections
4. Water system clean and flushed
5. Air purged from water system
6. Adequate water flow and pressure to the unit
7. Water temperature between 40 degrees F and 95 degrees F.
8. Condensate line clear and unclogged
9. Blower wheel free to rotate
10. Return air filter is installed
11. Access panels and enclosures are installed and secured
12. Thermostat on "Off" position

To start and balance the unit, follow these steps:

Adjust the room thermostat to its lowest setting and turn to "COOL" position. Set the fan switch on "AUTO." The unit should now be operating. If the unit has failed to start, see the trouble shooting guide section, Chapter 13.

Check for cool air at outlets after a few minutes of operation. Air flow in each area should be adjusted to the design airflow. The air temperature should drop 15 degrees F to 22 degrees F depending on the airflow across the unit and external static pressures. If the air is too cold (more than 22°F drop from entering air) or too warm (less than 16°F drop from entering air) re-adjust the outlets to provide the design air flow.

After the air flows are established and the return air temperature is about 80°F, check the current against the nameplate data. At these normal operating conditions, the current draw should be below the full load amperes stated on the unit

nameplate. This completes testing of the Solar Auxiliary Unit in its air-to-air cooling mode.

Turn the thermostat to OFF position. A "swishing" sound should be noticable at the unit indicating a properly functioning reversing valve.

Let the system pressure equalize for about two minutes. Adjust the thermostat to its highest setting and switch to "Heat." This tests the water-to-air heating mode provided that the thermal storage tank temperature is in the range of 50-80^{0}F. The circulating pump must be on, supplying warm water from the tank to the heat pump. After a few minutes warm air should be apparent at the heat ducts of the residence. Any vibrations, unusual noises or water leaks should be investigated.

To test the air-to-air mode of heating, set the bulb thermostats (1TAS, 2TAS, and 3TAS, discussed in Chapter 12) to simulate a storage tank temperature below 50^{0}F and an outside temperature above 10^{0}F. Set the house thermostat to call for heat. Observe the operation of the evaporator located out-of-doors. Check also that warm air is apparent through the heating ducts of the house within five minutes.

The "direct solar" mode of operation is tested as follows: Set the bulb thermostats 1TAS and 3TAS to simulate a storage tank temperature greater than 80^{0}F and set the house thermostat to call for heat. Observe that the circulating pump to the Solar Auxiliary Unit is on, the blower in the Solar Auxiliary Unit is on, but that the heat pump compressor is off.

The electric resistance heat provided in the Solar Auxiliary Unit gives a means of heating when there is such a prolonged period of overcast that the storage tank temperature drops below 50°F and the outdoor temperature is colder than 10^{0}F. In addition, it provides extra heat for those occasions when the occupant of the building wants to heat the space more quickly than can be done by the heat pump or direct solar coil alone. The first stage of electric heat can be tested by raising the setting on the thermostat 3 degrees or more above the present temperature. The thermal storage tank should be above 50^{0}F when this is done to avoid the possibility of the second stage of resistance heat being activated.

NOTE: Since Stage One electric resistance heat is used whenever a drastic increase in temperature is called for on the house thermostat, an energy conserving measure on the part of the homeowner is the changing of the thermostat setting by no more than two degrees at any time.

The second stage of resistance heat is normally only used when the thermal storage tank can give up no more heat before the risk of freezing becomes great, and the outdoor temperature is colder than 10^{0}F. These conditions are not likely to exist at the time the system is started and the operating modes tested, but they can be simulated by changing the settings on bulb thermostats 1TAS and 2TAS (See Chapter 12 for an explanation of each). If the storage tank is at 80^{0}F and the outside temperature 60^{0}F, set 1TAS at 85^{0}F and 2TAS at 65^{0}F. This should activate the second stage of resistance heat and the Solar Auxiliary Unit blower.

The glowing elements should be visible through a crack in the duct on top of the Solar Auxiliary Unit and warm air should be passing through the heat registers.

After being satisfied that the unit operates normally and the system is ready to run, the thermostat should be set on either "heat" or "cool" depending on the climatic conditions and temperature setting at the desired level of comfort.

Operation

The standard model is designed f indoor installation and when installed in an unconditioned space, the unit may not start in cool weather, (approximately 50^{O}F). In this case, it may be necessary to start the unit on cooling in cool weather for three to five minutes, then shut off and turn to heat after one minute shut down. (It may be necessary to repeat this procedure several times, especially when a crankcase heater is not used.)

The Climate Master Unit is equipped with high and low pressure safety controls, set to take the unit off the line under abnormal operating temperatures and flow conditions. If the unit goes off on one of the high or low pressure controls due to a known reason (if dirty filter or temporary lack of water or power failure the controls can be reset by setting the thermostat and power supply to "OFF", waiting a few minutes for the system pressures to equalize, and then turning to "Heat" or "Cool."

A popular but erroneous concept is that if the thermostat is set at extremely lower or higher temperatures the environment will cool or heat faster. It is good practice to set the thermostat at the desired level of comfort and not try to achieve comfort levels by constantly manually changing the thermostat from cooling to heating and cycling the unit.

Like any other type of mechanical equipment, the Climate Master Unit performs best when it is well maintained.

There is no substitute for the "know how" and experience of a competant refrigeration and air conditioning serviceman for your Solar Auxiliary Unit.

Maintenance

Regular service greatly improves the operating efficiency, reliability, and longevity of the Solar Auxiliary Unit.

Maintenance on the machine is simplified to the following items:

1. The heat pump is furnished with a one inch fiberglass throw-away type air filter. This unit should not be operated without this filter in place.

Filters should be inspected every three months and replaced when it is evident they are dirty. Operation becomes very inefficient with dirty filters. Three or four filter replacements may be necessary a year.

2. Condensate drains can pick up lint and dirt,

especially with dirty filters. Inspect the condensate pan and drain twice a year to avoid the possibility of overflow.

3. Check the contactors and relays within the control panel at least once a year.

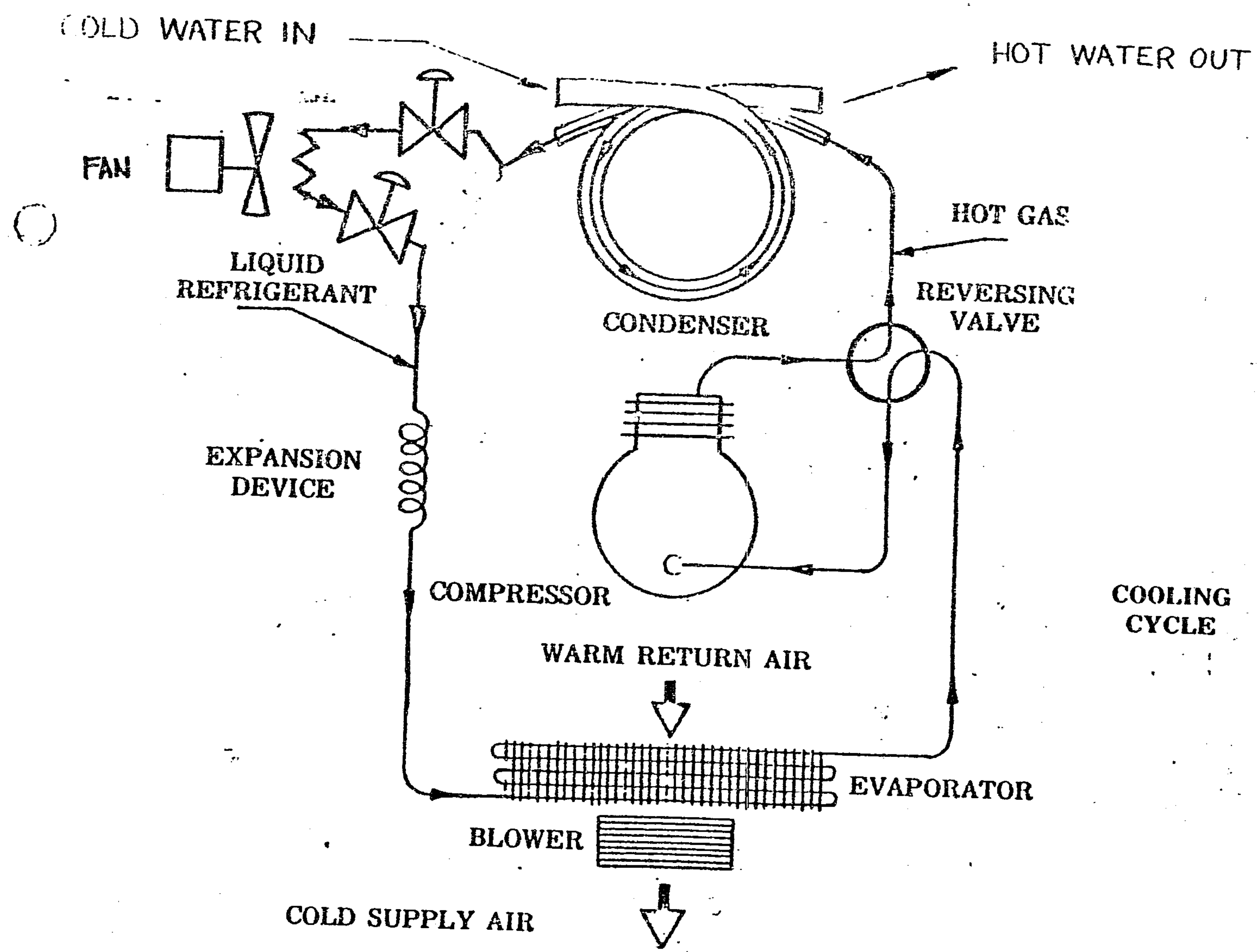
It is also good practice to check the tightness of the various wiring connections within the control panel, (especially when line power wiring to the machine is aluminum).

4. The blower motor on the "WC" heat pump models are rated permanently lubricated.

The "W" model blower motor requires oiling twice a year with a few drops of #20 SAE nondetergent oil. This should be done by a competent refrigeration service mechanic. It is good practice to inspect for belt wear and tension at this time. Correct belt tension is for the motor to be resting by its weight on the belt. If the belt is excessively tight, there will be excessive heat generated in the bearings and ultimate failure.

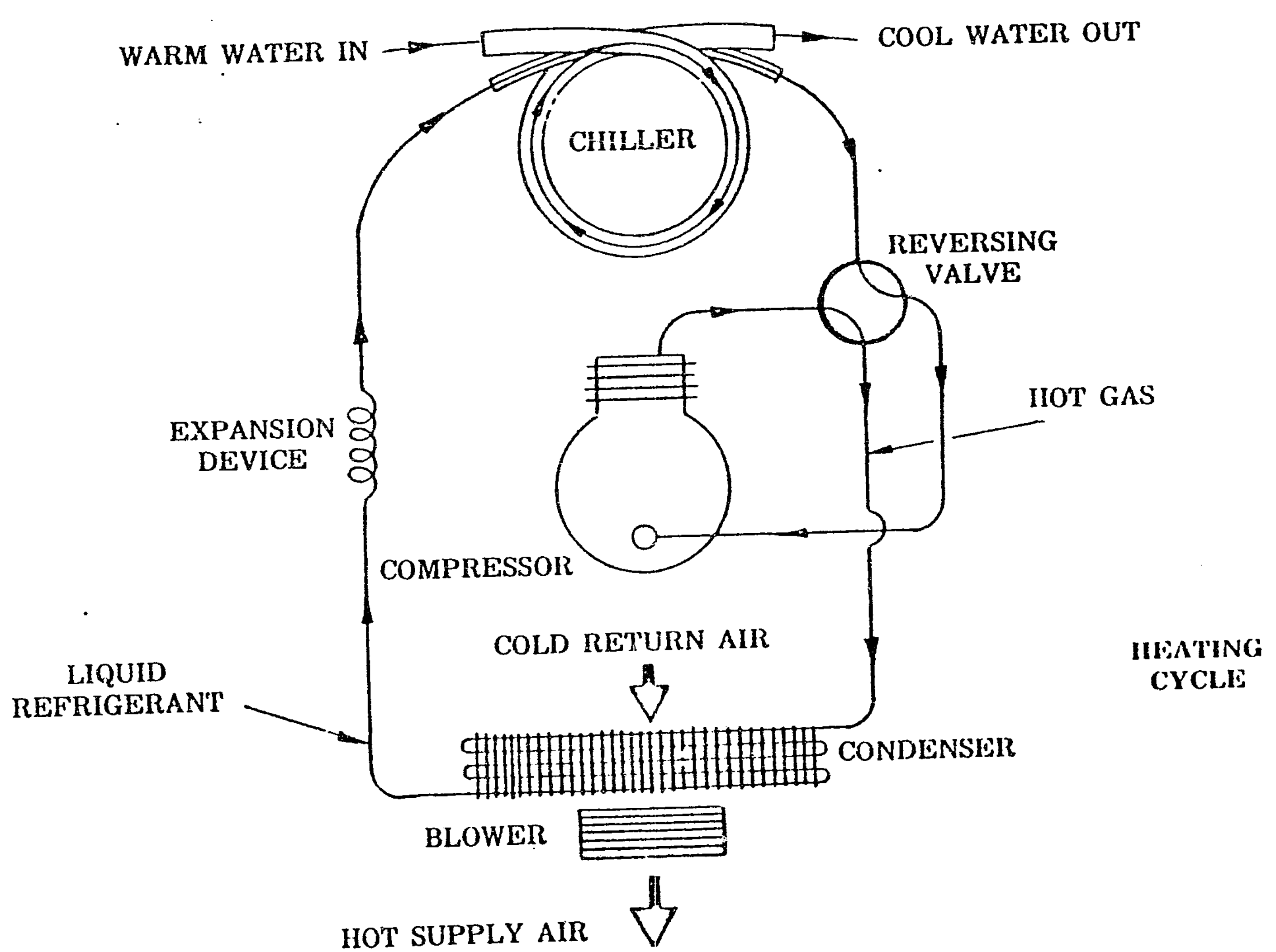
5. The water-to-air heat exchanger that provides the "direct solar" heating mode should be checked annually for adequate water flow through the tubes and air flow over them. Should restrictions in the piping be evident, flushing with a corrosive chemical may be required. This should be performed by a HVAC repairman.

FIGURE 10.1



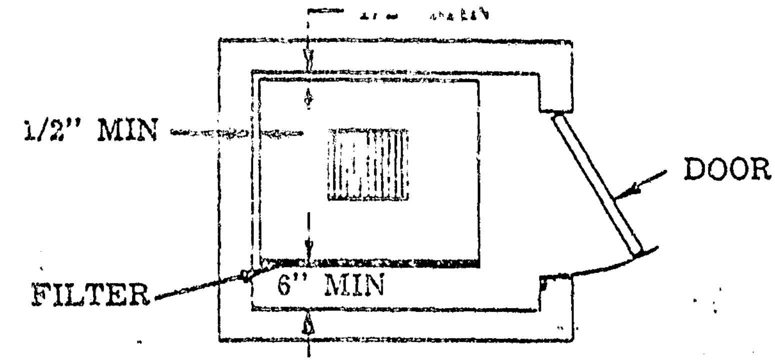
SOLAR AUXILARY UNIT IN AIR-TO-AIR COOLING MODE

FIGURE 10.2



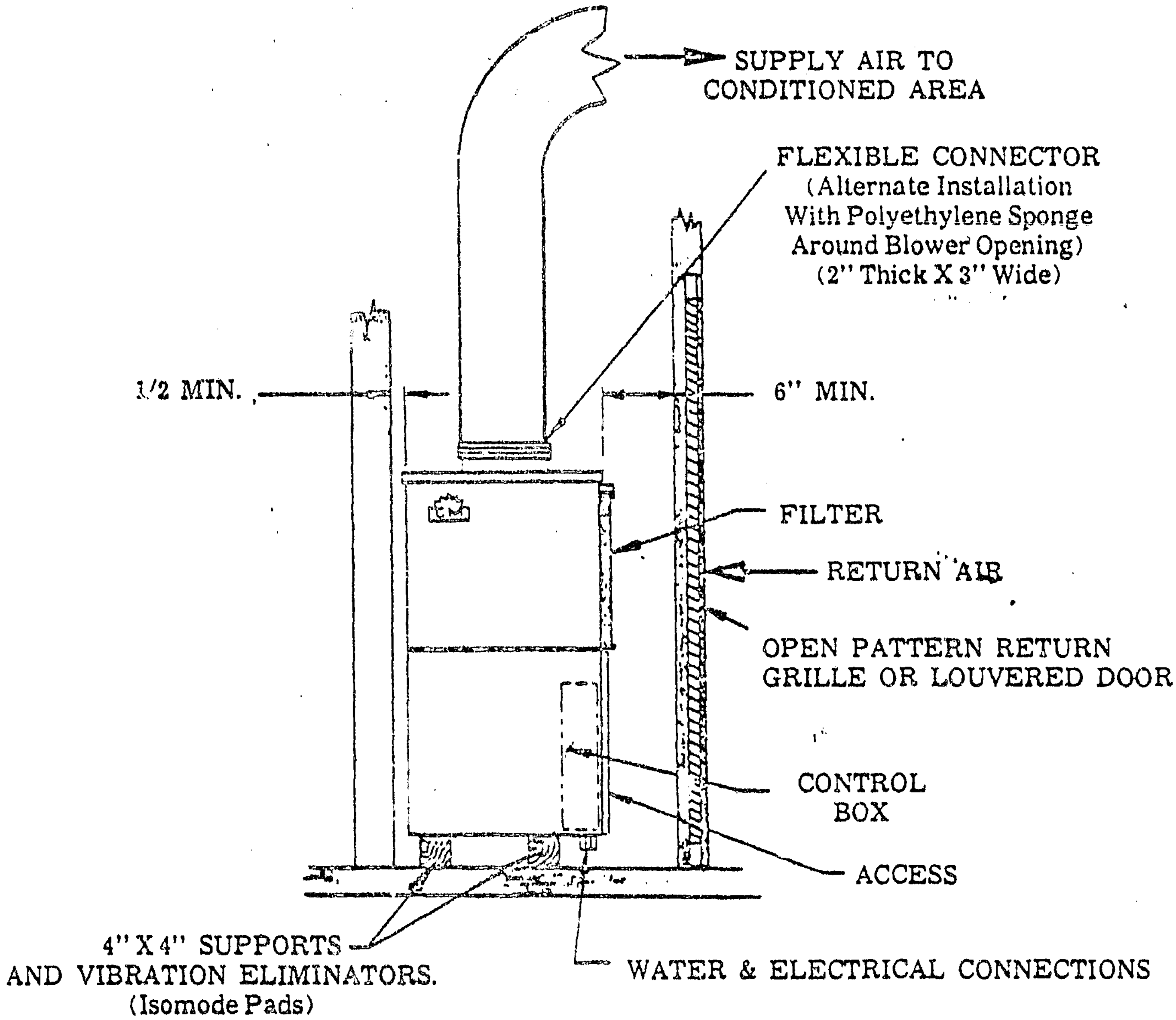
SOLAR AUXILARY UNIT IN WATER-TO-AIR HEATING MODE

FIGURE 10.3



UNIT SHOWN
LEFT HAND RETURN

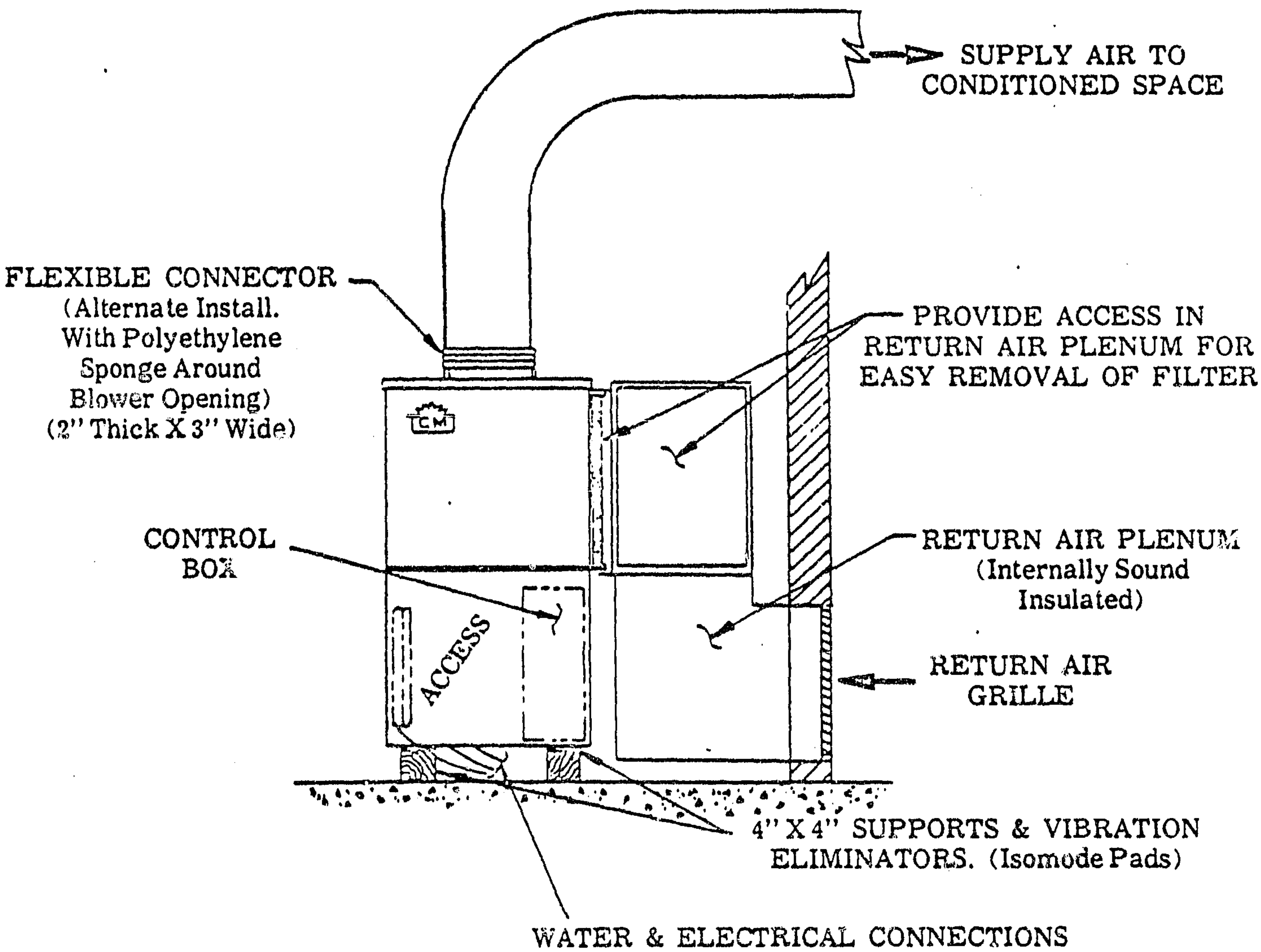
ALTERNATE INSTALLATION FOR QUIETER UNIT OPERATION



UNIT SHOWN
FRONT RETURN

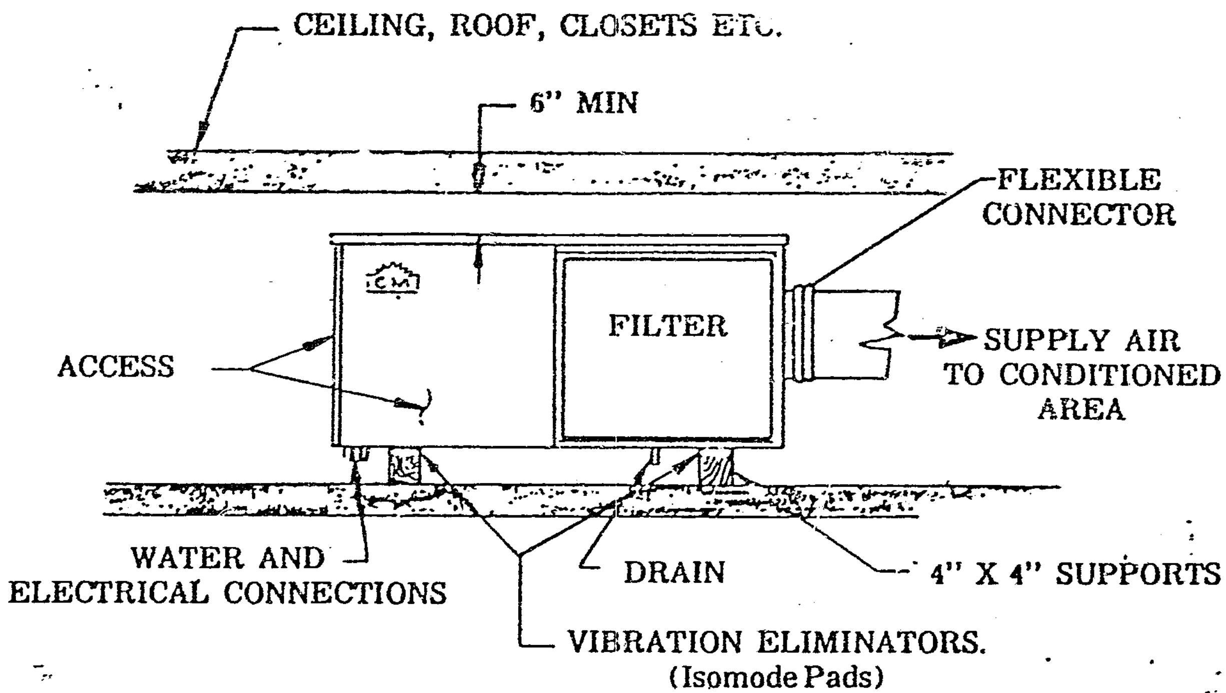
TYPICAL CLOSET INSTALLATION

FIGURE 10.4

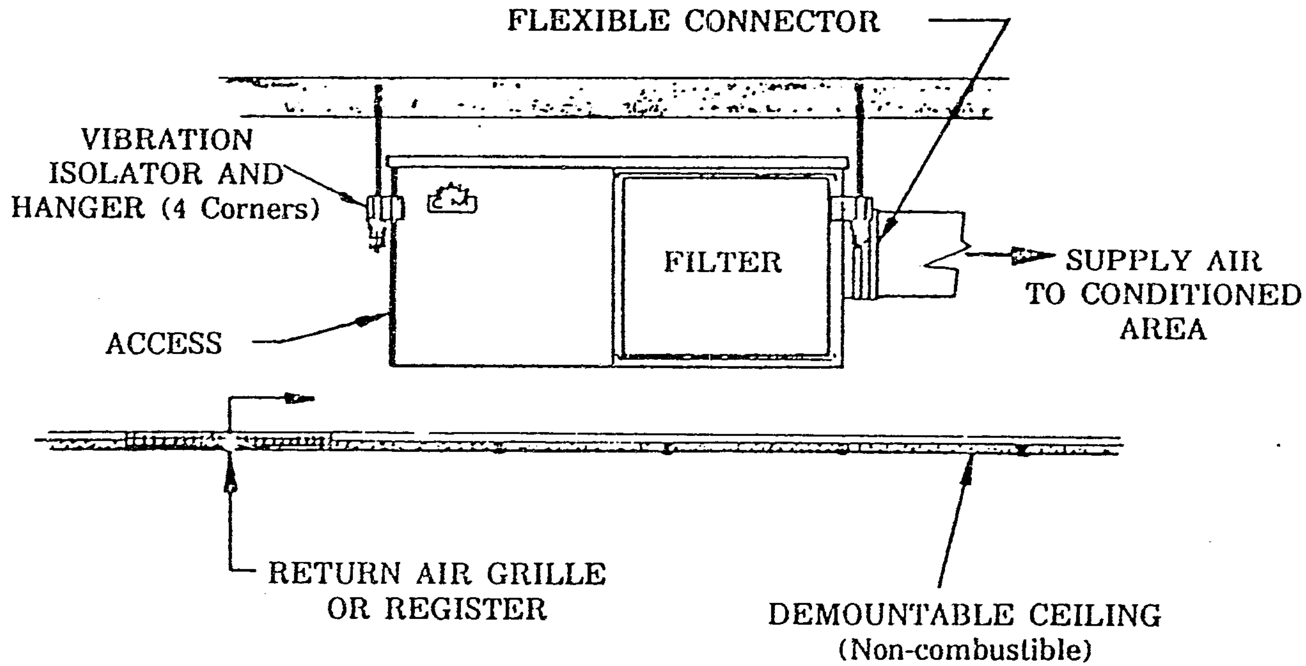


TYPICAL INSTALLATION FOR GARAGE
OR UTILITY ROOM

FIGURE 10.5



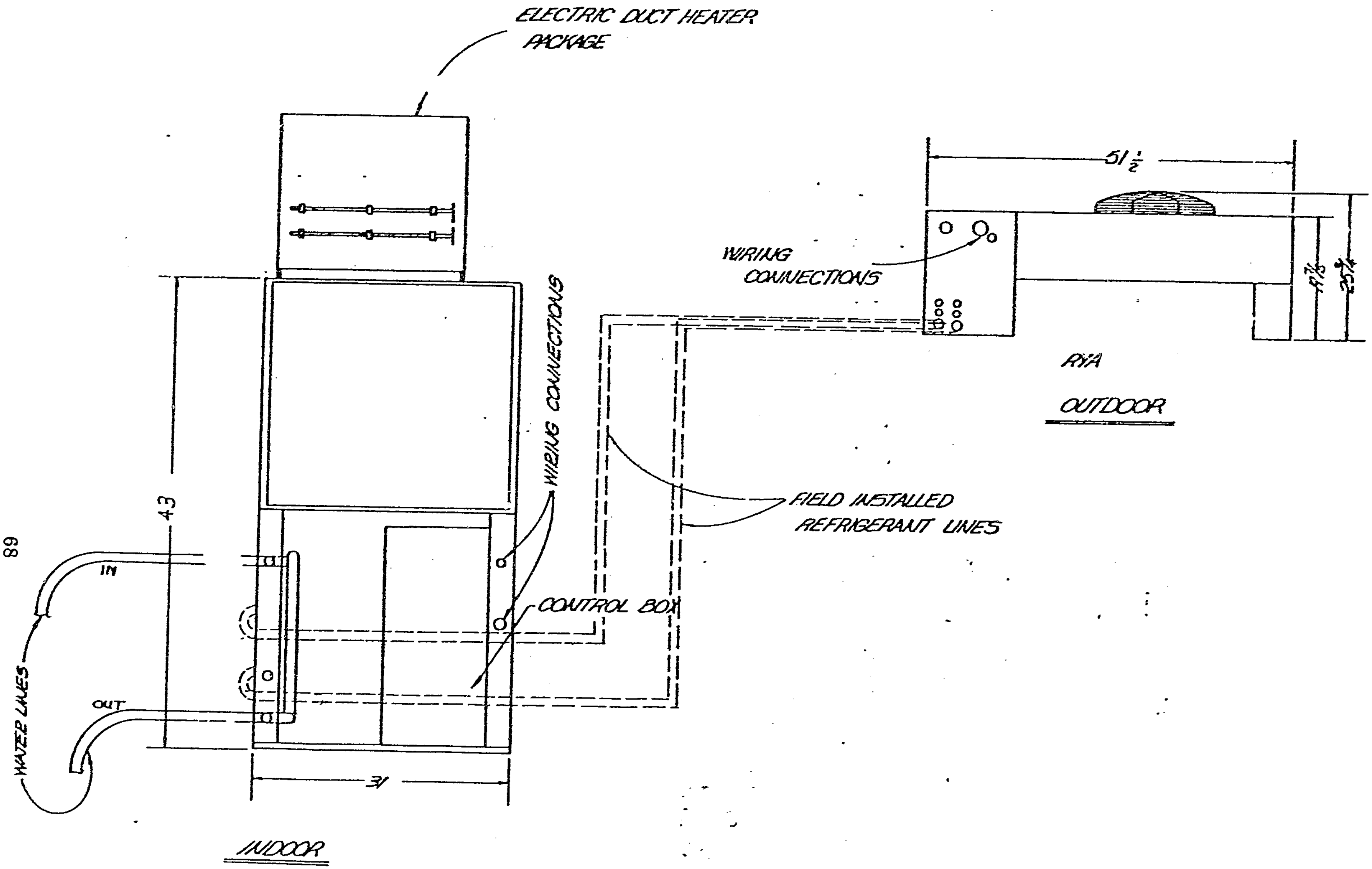
TYPICAL HORIZONTAL INSTALLATION



NOTES:

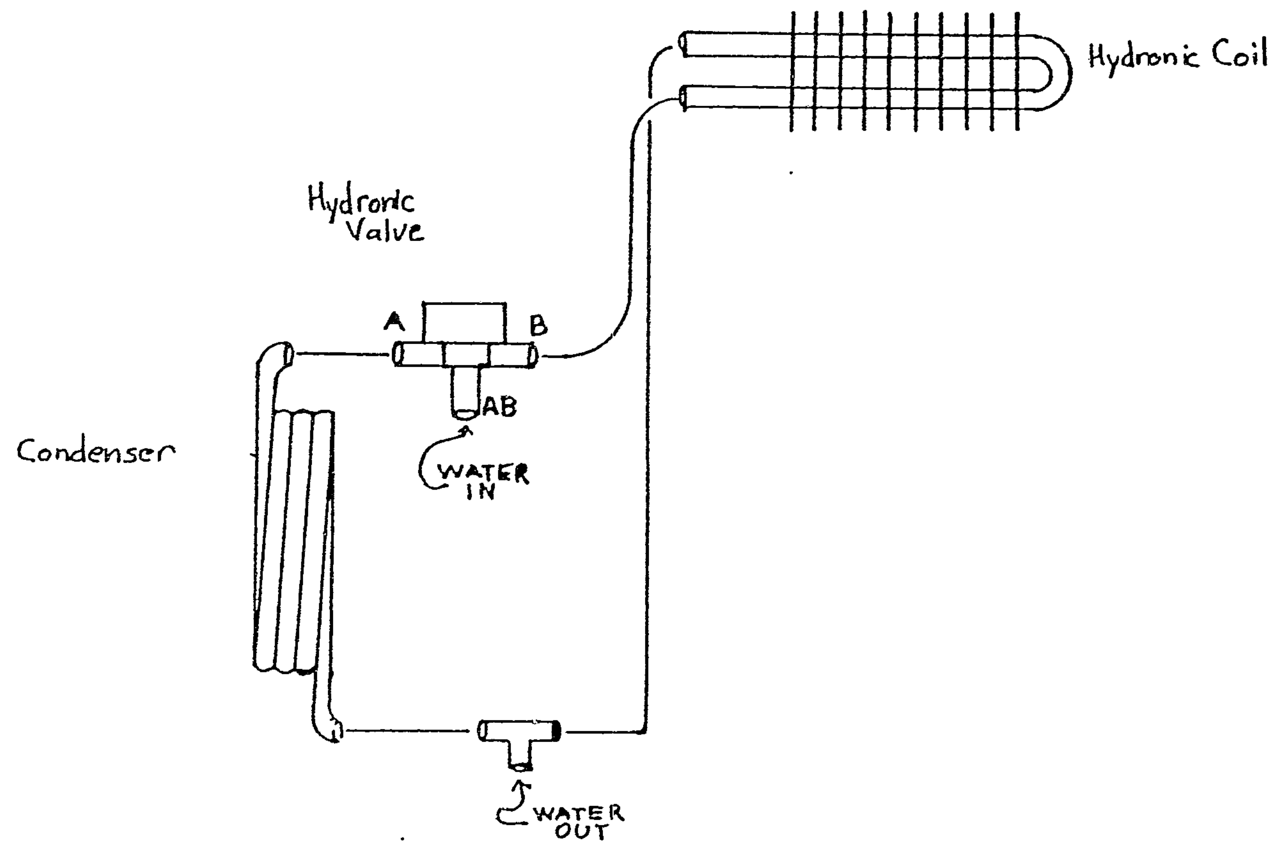
1. Construction of Return Air Plenum must comply with Building Codes.
2. Fire Dampers must be installed where required by Building Codes.

TYPICAL CEILING HANGER INSTALLATION



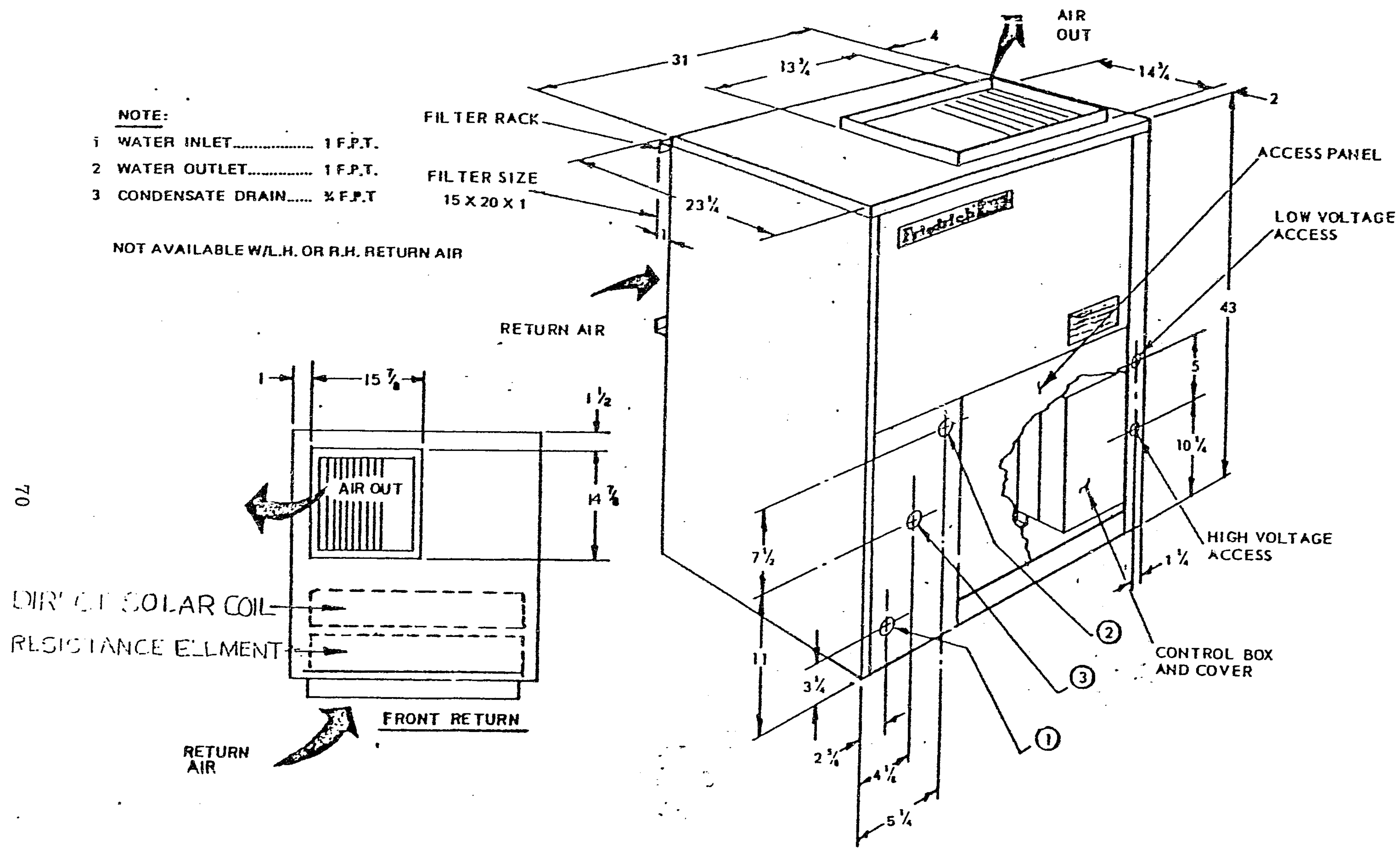
SOLAR AUXILARY UNIT

FIGURE 10.8



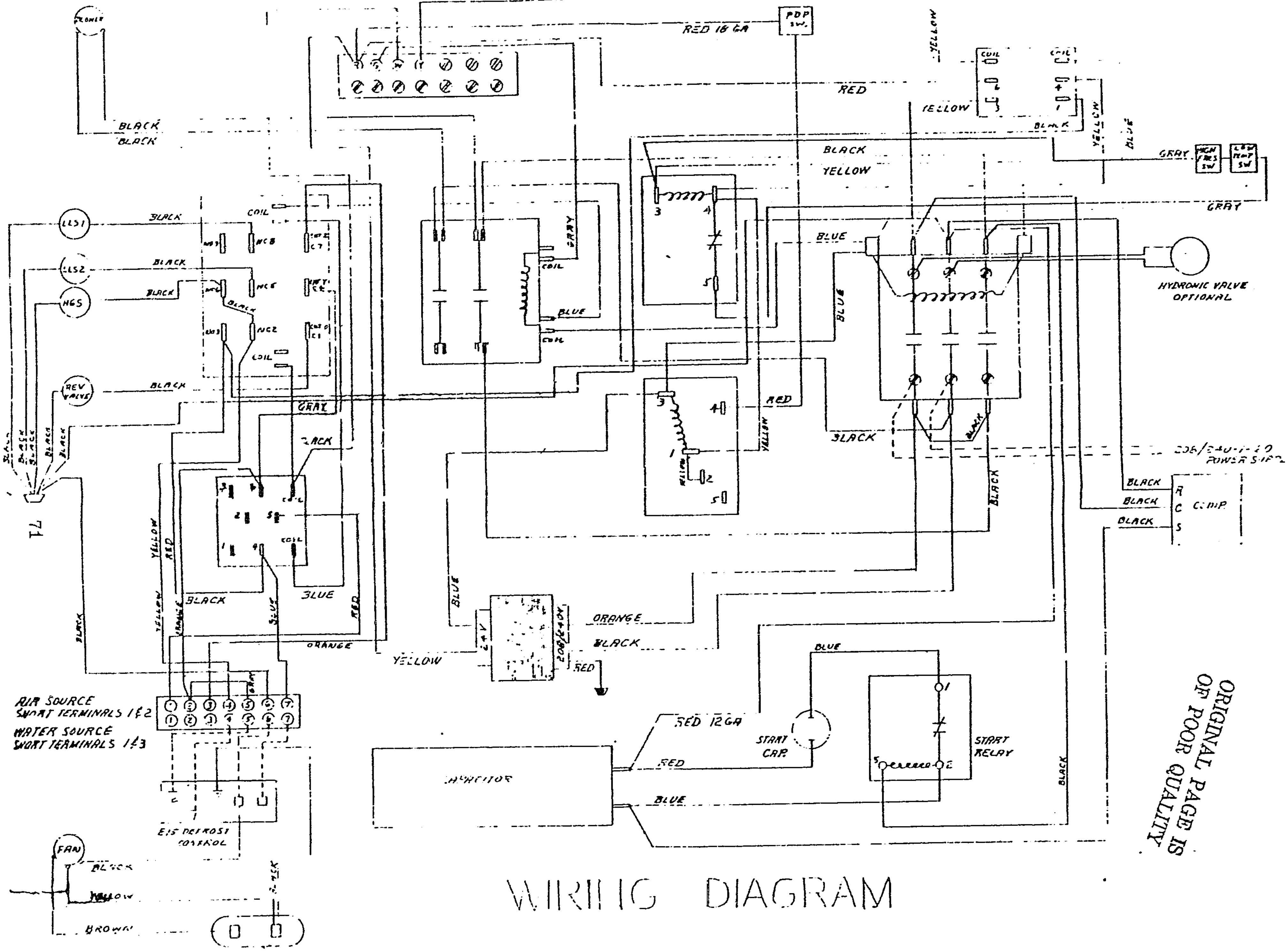
SOLAR AUXILARY UNIT PIPING SCHEMATIC

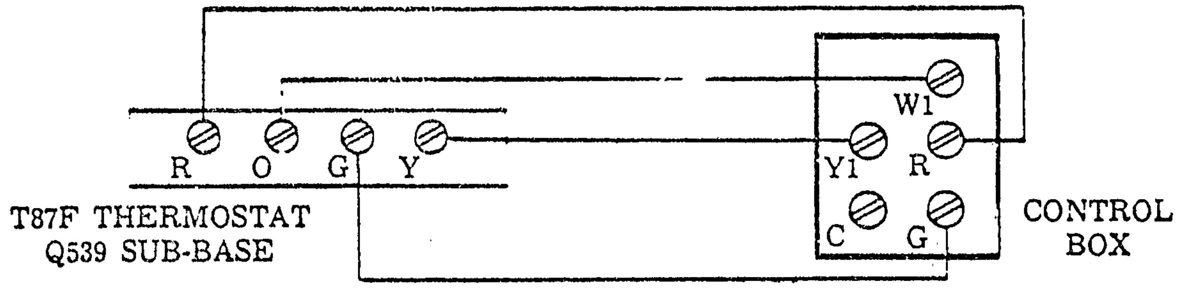
FIGURE 10.9



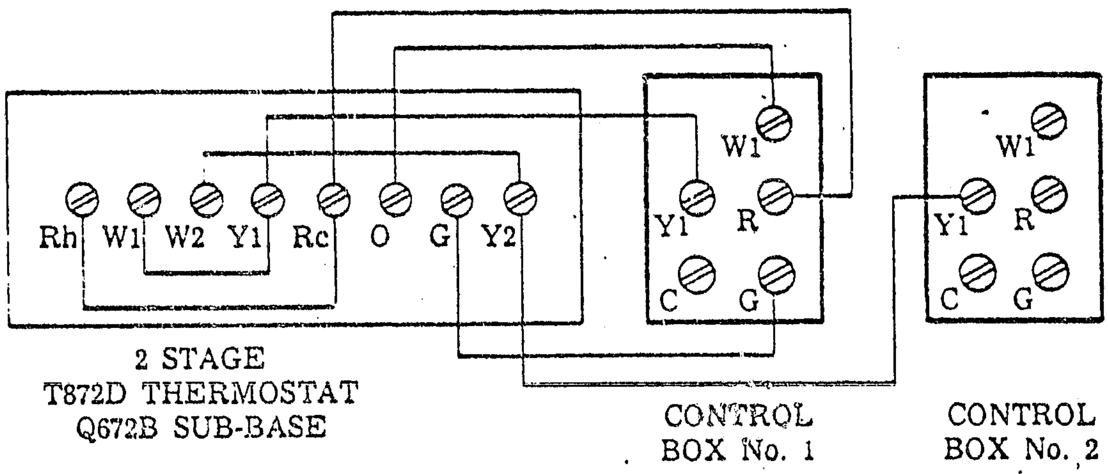
SOLAR AUXILARY UNIT ISOMETRIC DRAWING

FIGURE 10.10

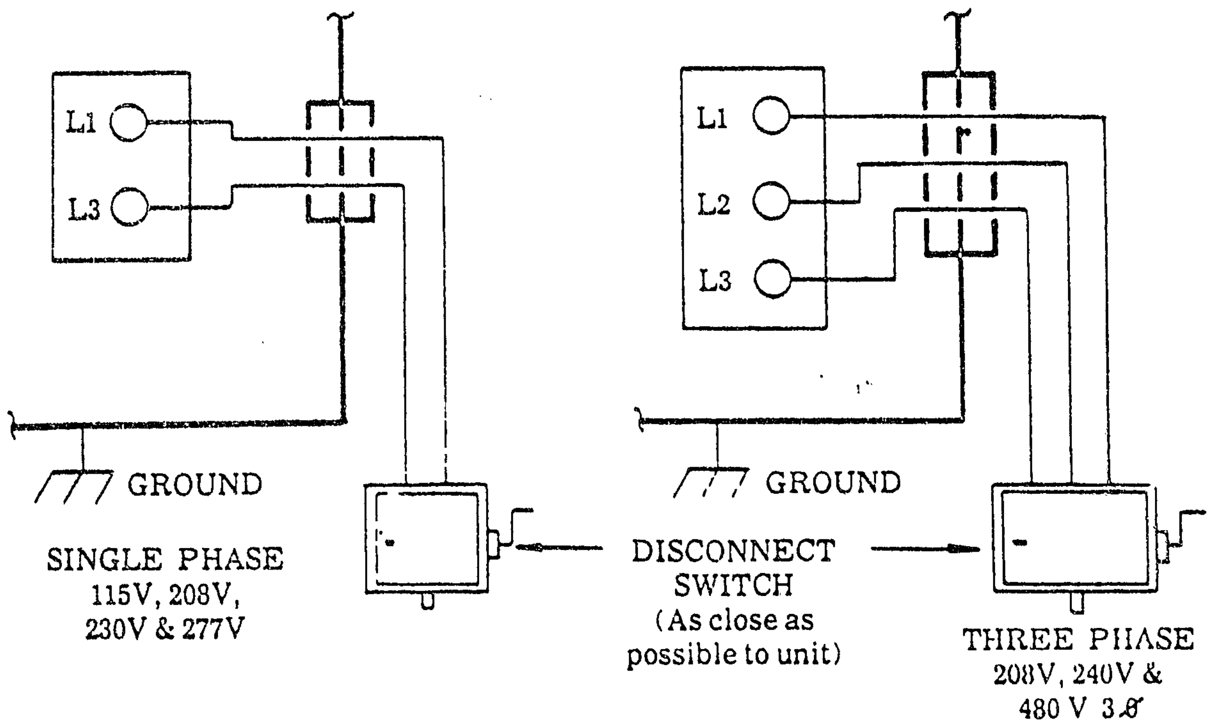

RED 18 GA
PDP SW.
RED
YELLOW
COIL
BLACK
BLUE
GRAY
HIGH PRES SW
LOW TEMP SW
HYDRONIC VALVE OPTIONAL
LLS1
LLS2
HGS
REV VALVE
NC8
NC6
NC2
C7
C1
ORANGE
208/240V
24V
208/240-1-60 POWER SUPPLY
COMP
CAPACITOR
RED 12GA
START CAP.
START RELAY
AIR SOURCE SHORT TERMINALS 1 & 2
WATER SOURCE SHORT TERMINALS 1 & 3
E/S DEFROST CONTROL
FAN
BROWN
WIRING DIAGRAM



LOW VOLTAGE WIRING — DUAL MODELS



POWER WIRING



FIELD WIRING DIAGRAMS

POWER AND LOW VOLTAGE WIRING

11.0 Space Heating Distribution System

The flow schematic for a single family residence is shown in Figure 11.1. This diagram will be used as the basis for a discussion of the heat distribution system. In multiple family units, more plumbing distribution lines will be present. The installer is reminded to work from the plans and specifications issued for his particular project rather than using the example flow diagram shown in Figure 11.1.

Installation

The plumbing involved should be done carefully to regularly accepted industry standards.

First, connect plumbing to carry water from the solar storage tank to the heat pump in the Solar Auxiliary Unit. This procedure begins at the suction end on pump P-2. The penetration of the thermal storage by piping is waterproofed with a pipe seal according to the instructions given in Chapter 3. The intake of the pipe is positioned six inches below the water level of the tank to take advantage of thermal stratification in the tank, since the highest water temperature will always occur near the surface.

A union and gate valve are installed outside the tank, as is a tee for the return piping from the collector array. A strainer is installed next, to permit trapping and removing any particles within the piping. Pump P-2 is then connected with a union and gate valve on either side to permit easy removal for servicing.

Near the Solar Auxiliary Unit a branch is made in the line so that the water may flow either through the heat pump or the "direct solar coil." A gate valve and union precede this junction. The diversion of flow from one path to the other is accomplished by solenoid valves V1 and V2. The lines converge beyond the Solar Auxiliary Unit, are connected to a tee, then safeguarded by a union and gate valve.

All valves and other plumbing specialties installed in this line must be connected in such a way that the trapping of air within the pipe is minimized. Gate valves on the suction side of pump P-2 should be sweated with their stems horizontal. Also, any pipe size reducers that are employed should be of the eccentric reducer type and should be installed with the flat side up. The inclusion of unions and shut-off valves on either side of the circulator and heat pump ensures that these components can be removed for repair or replacement without requiring the services of a plumber.

The highest point in the water line connecting the heat pump to the tank should be fitted with an air vent. All plumbing should be sloped upward to this point to avoid any trapping of air. A hand operated vent is more reliable and should be used instead of an automatic air vent. At the tank penetration of the return line, a shut-off valve, union, and pipe seal are employed.

When the plumbing is complete, the system is tested for leaks. This is done by attaching a pressure gauge and air compressor to the line. The air in the pipe is pressurized to 60 PSI and observed after 24 hours. If no drop in pressure has occured,

the system is concluded to be tight. If a pressure drop is found, the leak or leaks must be located and be stopped. This is done using soap around the plumbing connections while the air pressure inside the pipe is maintained. The pipes should not be filled with water until the absence of leaks has been verified.

Following pressure testing, the piping is insulated thoroughly. After the insulation is in place, the piping can be filled with water, the pump operated, and a maximum flow rate obtained using the balance valve downstream of pump P-2. This setting is done using a flow-meter. The flow is measured at various settings of the balance valve and the setting that gives the greatest flowrate noted. This should be the position of the balance valve throughout the life of the installation. If there are long runs of piping, this optimum setting may be with the balance valve wide open. If the total length of piping is less, a partially closed balance valve may yield the greatest flowrate. The reason for this is that the water pump performs best when loaded with some resistance to the flow. This restriction can be imposed by the balance valve if it is not already present due to long lengths of pipe.

Air ducting is run from the air outlet of the Solar Auxiliary Unit to the heated spaces of the dwelling. The ducting should be installed according to the building plans, and when installed, should be very thoroughly caulked with a silicone caulk. (Air leaks of 50% of the capacity of the ducting system are encountered in conventionally assembled, uncaulked ducts.) After caulking, the ducts should be insulated thoroughly. In laying out the ducts, these rules should be observed:

1. Sudden changes in the direction or velocity of the air stream should be avoided. In cases where sharp turns are indicated on the plans, the pressure drops at these corners should be minimized by the insertion of turning vanes in the duct.

2. At each branch outlet in the system dampers should be installed. This provides control over the flowrates within the ducts, a necessity for balancing the system.

3. The ducts should not be obstructed with piping, conduits, or structural members. Where obstructions are unavoidable, they should be streamlined with an easement or tear-drop, the length of which should be at least three times the thickness of the tear-drop.

Operation

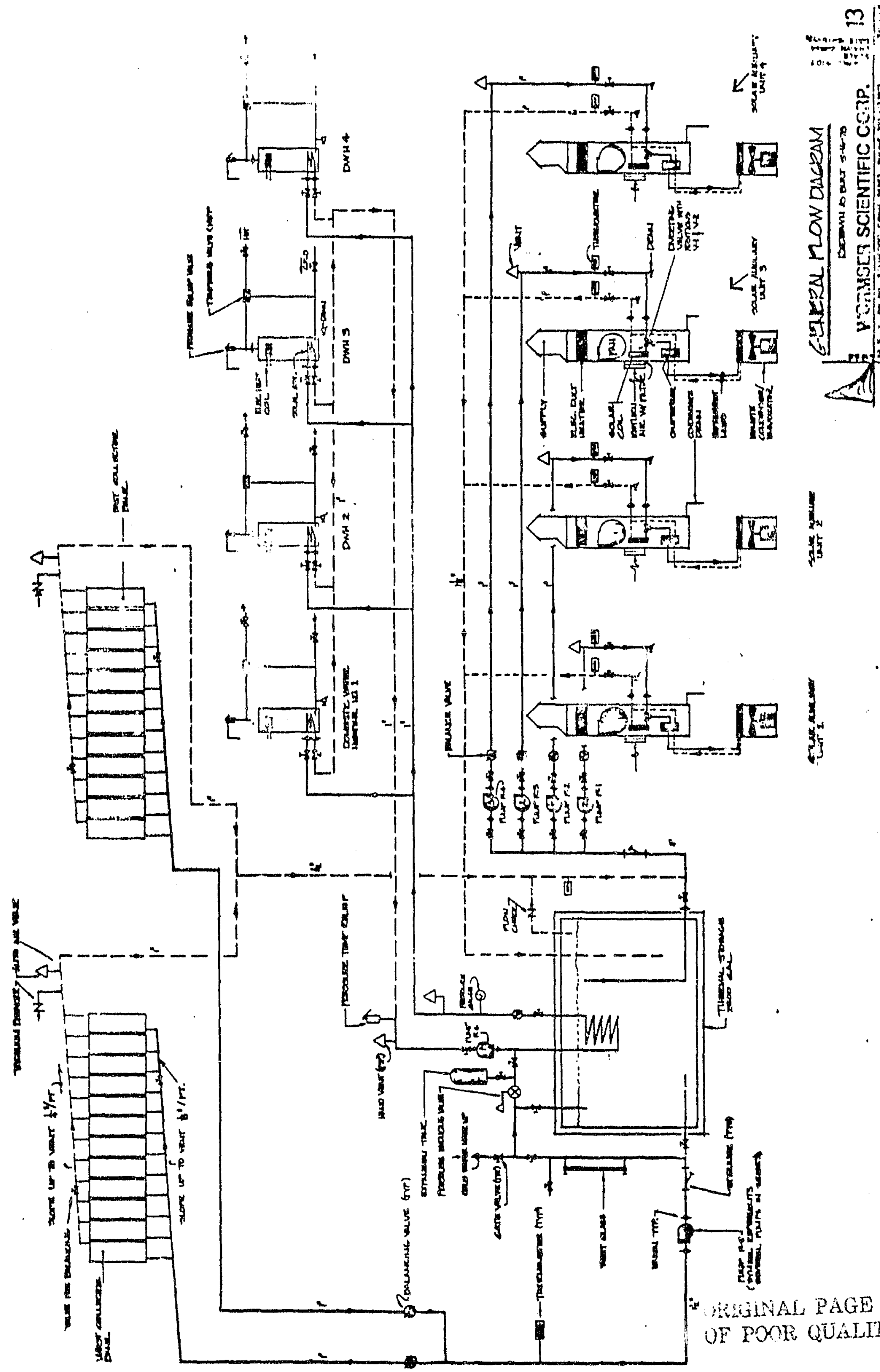
The operation of the space heating distribution system is controlled by the house thermostat and the control that operates the solar system. When the house is calling for heat and the thermal storage is above 40^{o}F, pump P-2 is activated. This circulates water to the Solar Auxiliary Unit, which passes through either the direct solar coil or the heat pump, depending on water temperature. Air picks up the heat and is circulated by blower through the duct network to warm the house. In the summer cooling is accomplished by the heat pump in the Solar Auxiliary Unit operating in the air-to-air mode. Cool air is removed from the heat pump by the blower and distributed through the ducts to the house.

Maintenance

The strainer in the line upstream of pump P-2 should be cleaned twice a year after monthly cleaning during the first three months of operation. To do this, close the gate valves on either side. Remove the strainer, providing a bucket or basin to catch the water that was in the pipe. Thoroughly clean the strainer, noting the particles caught on it as an indication of the relative cleanliness of the water in the storage tank. Then replace the strainer and open the shut-off valves, restoring water to the plumbing. Care must be taken to ensure that the pump does not operate while the valves are shut off, as damage can result from running the pump without water.

Maintenance of the Solar Auxiliary Unit is discussed in Chapter 10.

Figure 11.1



ORIGINAL PAGE IS
OF POOR QUALITY

12.0 Control System

The control system of the Pyramidal Optics Solar System regulates the operation of the components to automatically perform the time and temperature dependent tasks of maintaining comfort conditions in the dwelling. The solar system is shown schematically in Figure 12.1. Figure 12.2 is a "ladder" diagram showing the electrical connections that must be made for each system component to perform correctly. 120 Volt alternating current flows between Terminal L (line) and N (neutral), and 24 Volt current is available to the relays and soleniods downstream of the step-down transformer. The installer is reminded to work from the specifications issued for his particular project rather than from the examples presented in this manual. The explanation of Figure 12.2 following summarizes the operating modes of the solar system. The description is for the main control panel and control panel #1 located in Unit #2 West. The other three units function identioally.

Prior to detailing the operation of the controls, a brief explanation of the terms used is presented:

Symbol	Abbreviation	Device
	ATH, BTH	Collector Plate Sensors
	CR	Control Relay
	DC	Manual Disconnect
	FU	Fuse
	OL	Overload Device
	TAS	Thermostat
	TR	Time Delay Relay

1. Storing Heat from the collectors

A differential controller (1TDAS) operating between sensors 1ATH on the collector plate and 1BTH in the storage tank closes relay 1CR whenever the collectors are 15 degrees warmer than the storage tank and solar heat is available for collecting. Relay 1CR starts pump P-5, causing heat at the collectors to be transferred to the storage tank and circulation continues until the temperature difference between the collectors and the storage tank drops to three degrees. Relay 1CR then opens and current to pump P-5 is interrupted.

2. Direct Solar Mode

Three thermostats are involved in heating the home by the direct solar mode. These are the house thermostat 4TAS and two thermostats in the tank, 1TAS and 3TAS. The house thermostat calls for heat as the temperature of the living space drops by energizing terminal RH and W1. This closes relays which supply power to the space conditioning system along several wiring paths. Relay 1TR is energized supplying power to the air handler fan which must operate to carry away heating and cooling in all modes of operation. Relay 1TR is time delayed to prevent a blast of unheated air from striking the occupants. In the case that the solar storage tank temperature is above 80°F, both 1TAS and 3TAS

permit the flow of current to their respective relays, 2CR and 4CR. This turns on the direct solar solenoid, and 5CR, the relay for pump P-1. The result is that power is supplied to pump P-2 to circulate solar heated water from the tank to the Solar Auxiliary Unit. Power is also supplied to the solenoid valve. As is shown on the flow schematic, Figure 12.1, opening this valve diverts water through the water-to-air heat exchanger coil of the Solar Auxiliary Unit; in this mode, heating is 100% solar powered.

3. Solar Assisted Heat Pump Mode, Water-to-Air Operation

If the temperature of the storage tank water drops below 85°F but is still above 50 °F, the situration is similar to the direct solar mode of operation previously described. The positions of the house thermostat 4TAS and thermostat 1TAS are unchanged, but thermostat 3TAS removes power from relay 4CR. In the open position relay 4CR supplies power to the heat pump solenoid and 6CR, the heat pump heating relay. The effect of these two actions is to allow solar heated water to pass through the heat pump and to turn on the heat pump in the water source heating mode. As long as the conditions that dictated this mode of operation hold, solar heated water is used as the heat source for the heat pump. The coefficient of performance varies between 2.9 at 80°F and 2.3 at 50°F, the lower temperature limit of this mode.

4. Heat Pump, Air-to-Air Mode

Should the temperature of the storage tank water drop below 50°F as determined by thermostat 1TAS, the heat pump will shut off, the heat pump solenoid valve will de-energize, and the pump P-1 will stop. The house thermostat 4TAS still calls for heat and relay 1TR is still making contact, which keeps the heat pump fan operating. Thermostat 2TAS activates relay 3CR if the outside air temperature is above 10°F. This turns on the heat pump in the air-to-air mode using the outdoor evaporator. The heat pump remains in this mode, governed by thermostat 2TAS for as long as the outdoor temperature is above 10°F and the storage tank temperature is below 50°F.

5. Electric Backup Mode, Half Capacity

If the heat that is provided to the living space is insufficient and the space temperature continues to drop in any heating mode (direct solar, solar assisted heat pump in the water-to-air mode, or conventional heat pump in the air-to-air mode), terminal W2 in the house thermostat 4TAS is energized, which activates the electric duct heater at one-half capacity. When this amount of additional heating is sufficient to heat the building, the house thermostat's second stage becomes satisfied and the electric duct heater drops out. This second stage of the thermostat is activated whenever the setting is raised more than three degrees above the previous temperature.

6. Electric Backup Mode, Full Capacity

The second half of the electric backup heating is used in the event that the storage tank temperature as measured by thermostat 1TAS is below 50°F and the outdoor temperature is colder than 10°F. When this second condition is observed by thermostat 2TAS and the house calls for heat, the second stage of the electric backup heating is activated.

7. Heat Pump Cooling Mode (Not Solar Assisted)

In the summer as cooling loads are anticipated and heating requirements have ceased for the season, the occupant of the home must manually adjust the household thermostat 4TAS to the cooling mode. When this is done, a call for cooling is met by the energizing of terminals RC and Y1 in the thermostat, which activates relay 8CR. The contacts of this three pole relay, when closed, turn on the heat pump in the cooling mode including the heat pump fan to circulate cooled air to the house. In this configuration the heat pump utilizes the outdoor evaporator/condenser and functions in the air-to-air mode. When cooling lowers the interior temperature enough to satisfy the house thermostat, the heat pump and fan motor are turned off.

8. Domestic Hot Water Heating

The preheating of domestic hot water is controlled by the DHW differential controller, 2TDAS. Sensors 2ATH and 2BTH located at the DHW tank and in the solar storage tank, respectively report the temperature differential between the water in these vessels. When a temperature difference of +15°F is detected, relay 21CR is fired, which turns on circulating pump P-6. Solar heated water then flows through the heat exchanger located in the DHW tank, preheating that water. When the water has been warmed to within a temperature difference of 6°F, relay 21CR is deactivated and the pump stops.

Installation

The control system is installed prior to the application of a drywall in the interior space, to ensure that all wiring is concealed in the finished space. Power wiring must be run according to the applicable building codes, and the low voltage control wiring enclosed in conduit where it is exposed to damage. Both the low voltage and line voltage wiring must be run and secured in a workmanlike fashion.

1. Attach the control panel which comes complete with all relays and internal wiring to the wall of the mechanical room. This should be placed in a location convenient for initial wiring attachment and for periodic inspection and maintenance. As sensors are installed, wiring from them is run to the panel should be carefully labeled.

2. Install the house thermostat 4TAS to the wall of a room that will have a temperature representative of the entire house. The thermostat should be located approximately 5' above the floor and away from temperature modifying drafts, hot appliances, windows, and doors.

3. Install the collector differential controller 1TDAS sensors 1ATH and 1BTH. The controller is located in the control panel and low voltage

wiring must be run to the sensors at their points of attachment. Sensor 1ATH is mounted on an absorber panel near the middle of the absorber array. The sensor should be mounted between 1 and 2 inches from a flow tube. It is of vital importance to obtain good contact between the cylindrical sensor and the flat copper absorber. To achieve this, attach the sensor with a small sheet metal yoke using the sheet metal screws. Then place epoxy glue around the point of contact between the sensor and the plate to increase the area of contact.
Sensor 1BTH is installed in a 3/4" copper pipe capped at one end and inserted into the solar storage tank, as shown in Figure 12.3. The pipe is filled with a heat transfer oil or thermal grease and the sensor is inserted to the bottom of the pipe. This sensor is located near the bottom of the tank because thermal stratification will cause the coolest (and, therefore, most dense) water to be found there. The suction side of the collector loop circulating pump P-1 is located near the bottom of the tank to take advantage of this cooled water.

4. Sensors for the domestic hot water controller 2TDAS are installed next. They are sensor 2ATH located on the domestic hot water tank and sensor 2BTH in the solar storage tank. 2ATH is attached to the base of the DHW tank. Attach the sensor to the wall of the tank itself, or as close to the tank as possible on the pipe from the solar tank. Attach the sensor to the metal surface with quick setting epoxy, making sure that there is good contact to transmit the heat of the tank quickly to the sensor. Thoroughly and carefully insulate over the sensor. Attach extension wires to the short leads of the sensor and run these to the control panel. Label the ends of the wire.

Sensor 2BTH is installed in the copper pipe protruding into the solar storage tank, in which sensor 1BTH was previously installed. As shown on Figure 12.3, sensor 2BTH is to be mounted six inches below the surface of the water. Run low voltage wire from 2BTH to the control panel and label as before.

5. Install thermostat 1TAS in the copper pipe immersed in the solar storage tank that already contains sensors 1BTH and 2BTH. The procedure is slightly different with this instrument. The thermostat consists of a bulb and a short length of tubing which connects the bulb with a small control box. The bulb is inserted in the copper pipe until it is 12" below the water level, as shown in Figure 12.3. The control box is then attached to the top of the tank and low voltage wiring connected between the box and the control panel.

6. Install thermostat 3TAS in a manner similar to the hookup of 2TAS. The location, shown in Figure 12.3 is 3" down the throat of the suction end of pipe P1. The sensor is protected by a 1/2" copper pipe, capped at one end, which is lowered into it, until the bulb is approximately 12" below the level of the water in the tank. The 1/2" pipe is then filled with a heat transfer oil or thermal grease. The sensor box is attached to the top of the tank and low voltage wires run to the control panel.

7. Thermostat 2TAS is installed so that its bulb measures the outdoor air temperature while its box is mounted indoors. This may be done anywhere on the building. The choice of location will be influenced by the constraints of space, aesthetics, and the necessity of keeping the bulb protected from direct sunlight, vandals, and children. The box should be mounted indoors, with its low voltage wiring run to the control panel. The sensor bulb should be fed through a hole in the wall avoiding kinks in the line. Then, the hole should be caulked.

8. Connect the sensor wires, previously run to the control panel to the appropriate terminals in the panel using the wiring diagram supplied for the project. Wires should be neatly run and bundled with wire ties where necessary to avoid confusion inside the panel.

9. Power wiring is run between the pumps and the control panel in the mechanical room. All 120 volt wiring should be 12-2 or 14-2 with ground. Disconnects (switches) are installed in the lines as shown on Figure 12.2. It is extremely important to ground the body of each pump to eliminate the dangers of an electric shock.

Operation

Once the control system has been carefully installed and debugged, operation is automatic. The only seasonal adjustment is made at the house thermostat to shift from heating to cooling operation.

System Check Out:

The system should be tested in all of its modes to be sure that the system is completely functional. Conditions can be simulated by adjusting the bulb thermostats as follows:

Mode 1, Storing heat from Collectors

This mode can be simulated, however, it is recommend that it be checked on a sunny day so as not to disturb the setting of the differential controller. In brigth sun near noon, the pump P-5 should be running and the contacts of relay 1CR should be closed. The pump may need to be felt to determine whether it is on. It should be warm but not hot to the touch and be quietly humming.

Mode 2, Heating Directly from Solar Energy

If the tank temperature is above 80, moving the house thermostat up to call for heat should bring on this mode. Equipment on in this mode is pump P-1, air handler fan and solar water to air coil. If the tank is below 80 when check out is being done, sensor 3TAS can be adjusted by screwdriver to click on and if the tank is below 50, 1TAS can be similarly adjusted to click on. The direct solar solenoid should be open (humming) in this mode.

Mode 3, Solar Assisted Heat Pump, Water to Air

Adjust the bulb sensors 1TAS and 3TAS to simulate

a tank temperature between 50 and 80. The heat pump solenoid should be on and the heat pump compressor should be on. (The compressor is the watermelon shaped object within the cabinet which should be vibrating to the touch.)

Mode 4, Heat Pump Air to Air

Adjust bulb thermostats 1TAS, 2TAS, and 3TAS to simulate a tank temperature of below 50 and an outside temperature of above 10°F. The outdoor unit should be operating and both the heat pump compressor and the air handler fan should be on.

Mode 5, Electric Backup Mode, Half Capacity

This mode comes on when the house thermostat falls to its second stage. This can be simulated by setting the heat up as high as it will go. (Bulb thermostats 1, 2, and 3TAS are in their "normal" setting.) Glowing of the heat strips should be observable through the crack just above the strip. The air handler should be operating.

Mode 6, Electric Backup Mode, Full Capacity

Testing of this mode can be made by setting 1TAS, 2TAS, and 3TAS to simulate an outside temperature of below 10 and a tank temperature below 50°F. The heat strip not activated in Mode 5 should not be glowing. The air handler should be operating. The strip heater coils operate for a few minutes after the house thermostat is satisfied because they are controlled by thermal relays which require a period of cooling after the coil is de-energized before their contacts open.

Mode 7, Heat Pump Cooling

Simulate this mode by moving the house thermostat to the cooling position. The outdoor unit should come on, the air handler should come on, and the heat pump compressor should be working.

Mode 8, Domestic Hot Water Heating

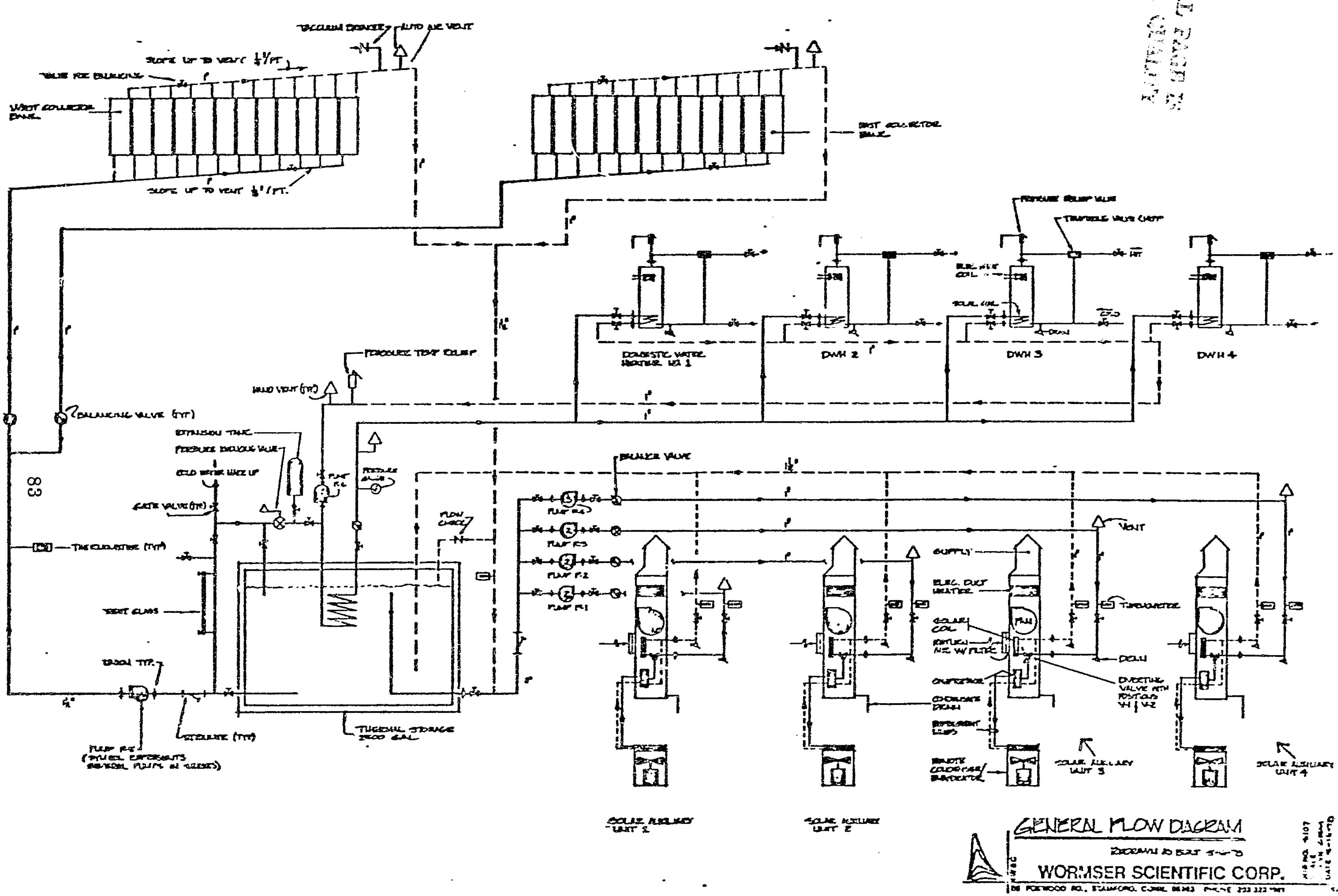
Simulate this mode by opening a hot water tap in the house. After a few minutes the incoming cold water should produce a temperature difference between the DHW tank and the solar tank large enough to start the pump P-6 (assuming a reasonably warm solar tank).

Maintenance

An annual inspection of the control panel should be carried out. First, disconnect power to the panel by releasing the internal fuse. Second, disconnect power to the contacts of the relays by cutting off the mechanical equipment at the appropriate disconnect switches. Inspect the contacts of the relays and check all wire connections for tightness.

Clean out all accumulated dust and dirt. Reconnect all equipment and run through system checkout to insure that all modes are functioning.

Figure 1.21



DWH 2
DWH 3
DWH 4
GENERAL FLOW DIAGRAM
WORMSER SCIENTIFIC CORP.

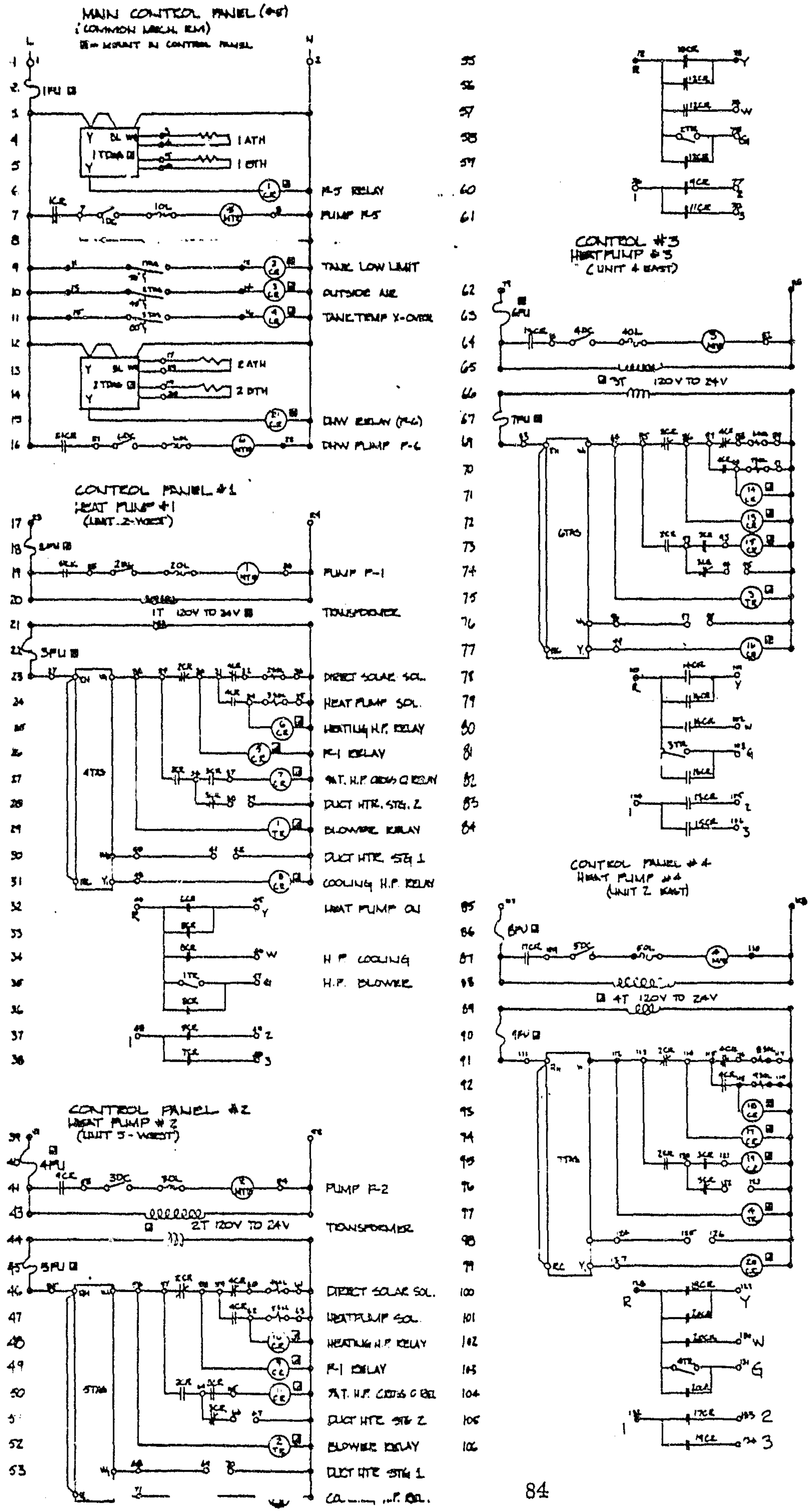

MAIN CONTROL PANEL (#5)
(COMMON MECH. RM)
CONTROL PANEL #1
HEAT PUMP #1
(UNIT 2-WEST)
CONTROL PANEL #2
HEAT PUMP #2
(UNIT 5-WEST)
CONTROL #3
HEAT PUMP #3
(UNIT 4 EAST)
CONTROL PANEL #4
HEAT PUMP #4
(UNIT 2 EAST)
PUMP P-5
TANK LOW LIMIT
OUTSIDE AIR
DHW PUMP P-6
PUMP P-1
TRANSFORMER
DIRECT SOLAR SOL.
HEAT PUMP SOL.
HEATING H.P. RELAY
P-1 RELAY
DUCT HTR. STG. 2
BLOWER RELAY
DUCT HTR. STG 1
COOLING H.P. RELAY
HEAT PUMP ON
H.P. COOLING
H.P. BLOWER
PUMP P-2
120V TO 24V

Figure 12.2

ıtermination of tank temperature is made by a bulb thermostat (3TAS energizing control relay 4CR) placed in the outlet of pe returning from the collectors. This is the same pipe which feeds the space heating equipment. This arrangement allows heating from the collectors bypassing the storage tank when it is below 85°.

ıre 12.2 (contd)

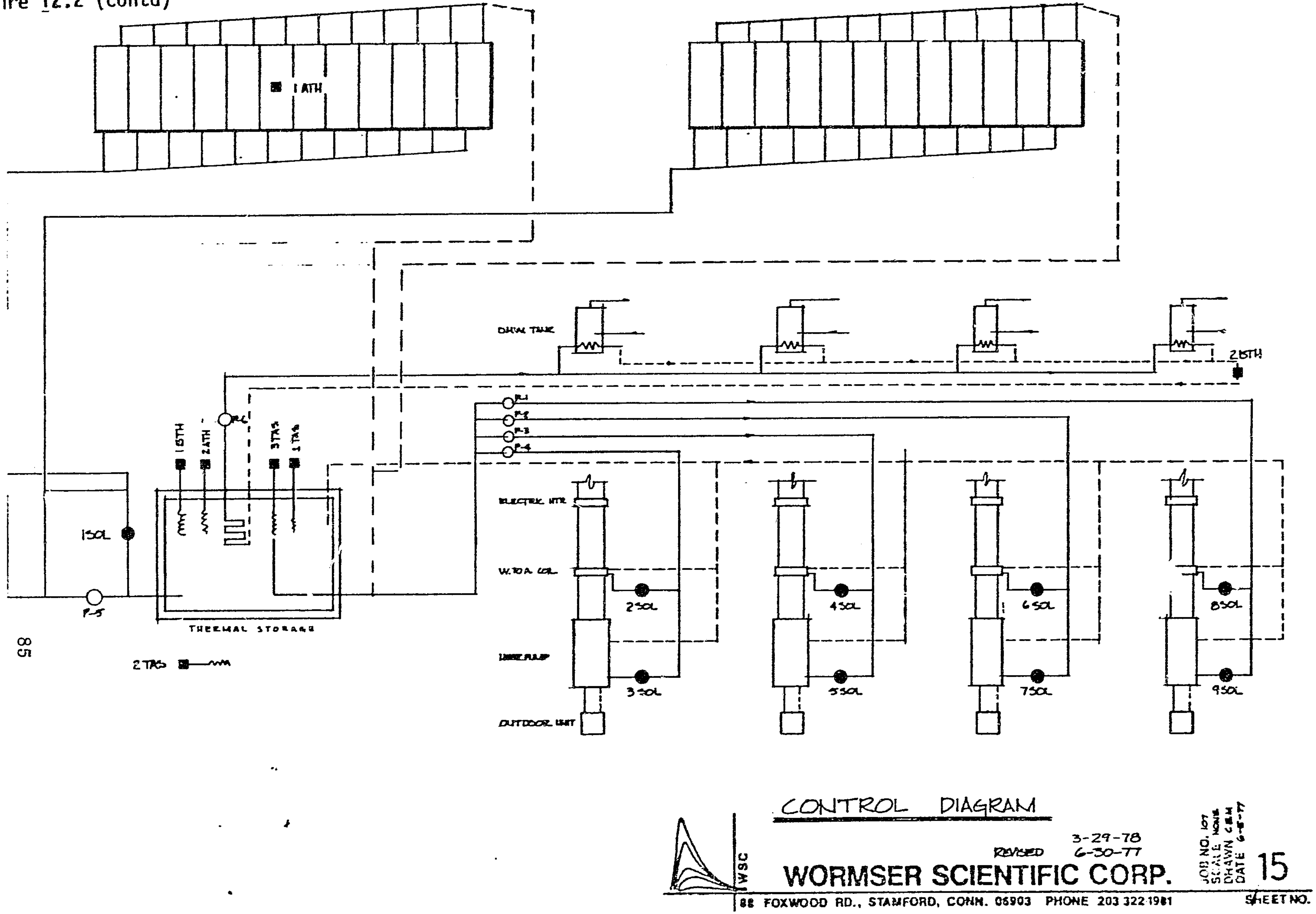
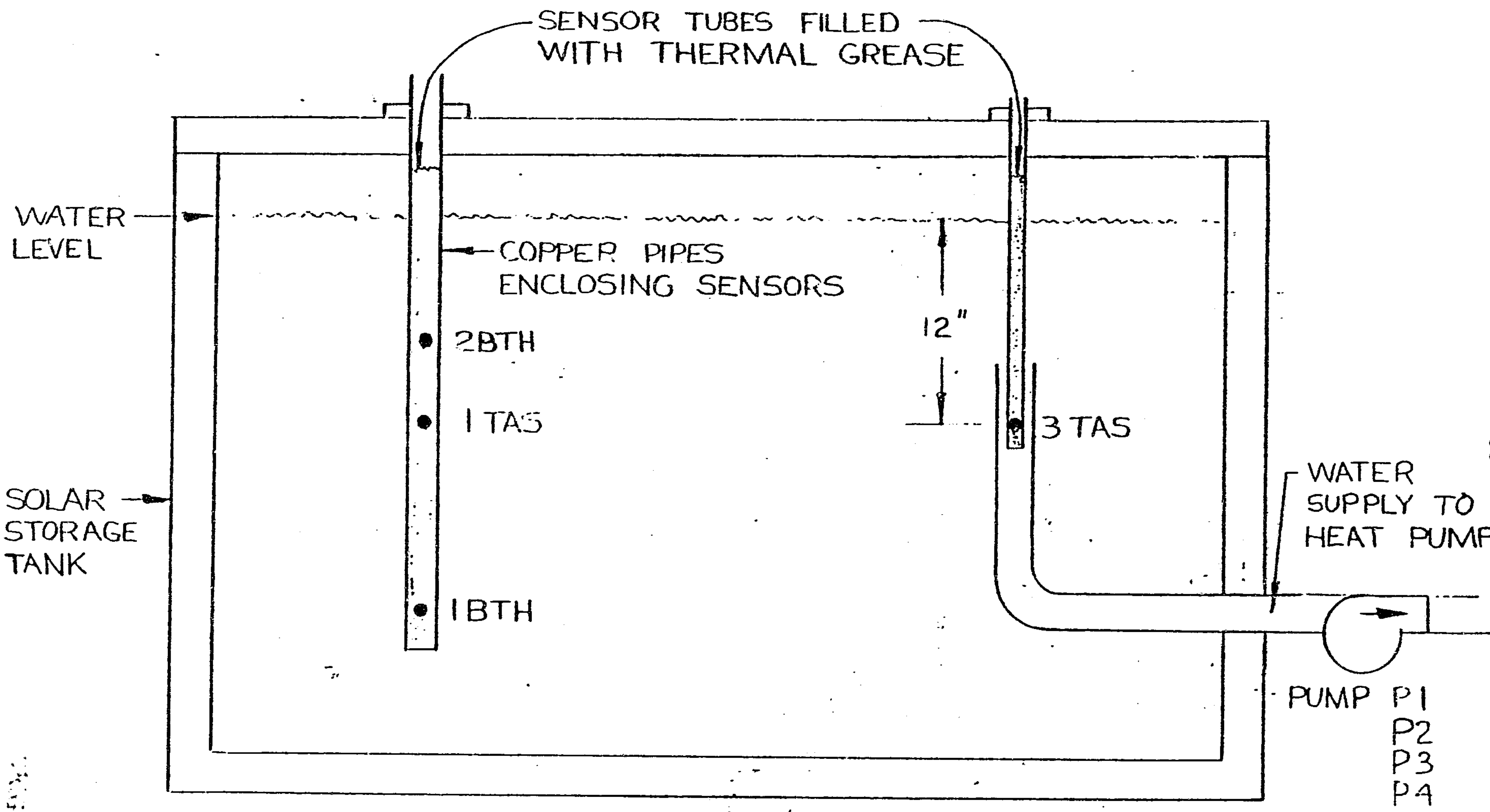


FIGURE 12.3



STORAGE SENSOR LOCATIONS

13.0 Trouble Shooting Chart

Storage System:

Complaint	Possible Cause	Correction
Tank Temperature Too Low	Pump P1 not functioning	-Check that valves are set correctly. -Check that pump is receiving 115V current. -Check that pump rotates; if frozen, repair or replace.
	Clogged Strainer	-Clean Strainer. Remedy any addition of sediment to tank.
	Movable flap at wrong angle.	-Adjust flap angle manually; check Solar Altitude Compensator for correct operation.
	Pipe Leak in Collector Loop.	-Find Leak; Correct.
	Excessively Dirty window.	-Wash solar window with water, soft cloths
	Dusty reflective surfaces.	-Dust reflective surfaces with damp cloth.
	Clog in Collector Piping	-Locate and remove stoppage.
	Flowrate through collector loop too low.	-Readjust balance valve.
	No flow through collectors (collectors hot to touch)	-Adjust balance valves on collector See Chapter 7. -Check for correct operation of air vent (air should blow out of line when pump turns on, suck in when pump shuts off) -Unclog stoppage in manifolds . -Replace manifolds. -Blow out blockage in collectors. -Replace collectors.
Tank Level too low.	Hole in Liner or faulty pipe seal.	-Shut off solar system; allow tank to drain through leak until water level stops dropping, leak is then somewhere on the waterline - drain tank; repair leak; refill tank;
	Excess evaporation	-Make tank more watertight above waterline.

Solar Window Glazing:

Complaint	Possible Cause	Correction
Broken Solar Window	Projectile	-Replace pane as described in Ch.5
Window Leaks	Imperfect gasket installation	-Locate leaking pane and caulk its perimeter by running a continuous bead of silicone
Glazing yellows	Poor composition of plexiglass	-Replace affected panes.
Low transmission	Accumulation of dust, leaves	-Wash window from the outside with hose, long-handled mop
	Snow Covers window	-If snow does not slide off by noon of the first sunny day after snowfall, clean snow from window with long-handled non-abrasive broom.
Attic too hot to work in.	Sunlight Admitted through glazing.	-Work at night or cover outside of glass with tarpaulin.

Reflective Mirror System:

Complaint	Possible Cause	Correction
Reflective Film Delaminates	Glue failure	-Replace panel by covering old board with new or remove and replace panel.
Moving reflector does not change angle	Malfunction in Solar Altitude Compensator	-Manually change flap angle, locate and correct fault in S.A.C. (Check slip clutch first)
Film loses reflectivity	Accumulation of dust on the surface.	-Clean with a damp cloth.

Absorber Plate System:

Complaint	Possible Cause	Correction
Insufficient Flow in Absorbers	Air Blockage	-Vent air then clean or replace automatic air vent.
	Pump malfunction	-Repair or replace pump.
	Tank level has fallen below level of pump intake.	-Check for leak or excessive evaporation; refill tank
	Sediment in pipes	-Locate blockage; blow out with compressec air.

Absorber Plate System (cont'd)

Complaint	Possible Cause	Correction
	Balance valves set incorrectly.	-Adjust balance valves as described in Ch. 8

Collector Piping System:

Complaint	Possible Cause	Correction
Collector Pump P-1 Does Not Operate.	No Current to pump	-Check manual disconnect; fuse in control panel.
	Differential controller malfunction.	-Test sensors on tank, absorber.
	Pump relay malfunction.	-Check for loose terminals; burned out coil or contacts.
	Wiring fault in pump.	-Check pump continuity, amperage draw.
	Pump Airbound	-Vent air at pump
	Insufficient water supply (pump overheats)	-Clean strainer; check that valves are open.
	Debris in pump	-Dismantle; clean pump.

Domestic Hot Water System:

Complaint	Possible Cause	Correction
No pressure in DHW line when pump is off.	Leak	-Locate; repair leak.
Low pressure in DHW line.	Escape of water through pump	-Add makeup water to loop.
DHW pump does not turn on	Controls malfunction	-Check DHW control sequence
	Pump Malfunction	-Repair or replace pump
DHW pump runs continually	Differential controller malfunction	-Check that sensors are in the correct locations, well-insulated; check operating modes of DHW controller

Solar Auxiliary Unit:

Complaint	Possible Cause	Correction
Entire Unit Does not Run	Blown Fuse	-Replace fuse or reset circuit breaker
	Broken or loose wires	-Replace or tighten the wires.

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
Entire Unit does not run	Voltage supply low	-If voltage is below minimum voltage specified on dataplate, contact local power co.
	Low Voltage Circuit	-Check 24 volt transformer for burnout or voltage less than 18 volts.
	Thermostat	-Set thermostat on "COOL" and lowest temperature setting, unit should run. Set thermostat on "HEAT" and highest temperature setting, unit should run. Set fan on "RUN", fan should run. If unit does not run in all three cases, the thermostat could be wired incorrectly, or faulty. To ensure faulty or miswired thermostat disconnect thermostat wires

Complaint	Possible Cause	Correction
		at unit and jumper between "R", "Y", "G", and "W" terminals and unit should run. Replace thermostat with correct thermostat only. A substitute may not work properly.
Blower runs but compressor does not	Voltage supply low	-If voltage is below minimum voltage specified on the dataplate, contact local power company
	Thermostat	-Check setting, calibration, and wiring.
	Wiring	-Check for loose or broken wires at compressor, capacitor or contactor.
	High or Low Pressure Controls	-The unit could be off on the high or low pressure cut out control. Reset the thermostat to "OFF." After a few minutes turn to "COOL." If the compressor runs unit was off on high or low pressure (SEE complaints for possible causes.) If the unit

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
		still fails to run, check for faulty switch by jumpering the high and low pressure controls individually.
		-Check that the heat pump is receiving the manufacturer's minimum recommended flow rate of water.
	Defective Lockout Relay	-Stuck open, does not reset when power is turned off.
Blower Operates but Compressor does not	Defective capacitor	-Check capacitor if defective, remove, replace and revise correctly.
	Seized Compressor	-Try an auxiliary capacitor in parallel with the run capacitor momentarily. If the compressor starts but the problem reoccurs on starting, install an auxiliary start kit. The hard

Complaint	Possible Cause	Correction
		start kit comprises of a recommended start relay and correctly sized capacitor. If the compressor still does not start, replace the compressor.
	Compressor overload open	-In all cases an 'external' or 'internal' temperature sensitive compressor overload is used. If the compressor dome is too hot to touch the overload will not reset until the compressor cools down. If the compressor is cool and the overload does not reset there may be a defective or open overload. If the overload is external replace the overload otherwise replace the compressor.
	Compressor Motor Grounded	-Internal wiring grounded to the compressor shell. Replace the compressor. If compressor burnout, install filter dryer at suction line.

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
	Compressor Windings Open	-Check continuity of the compressor windings with an ohmmeter. If the windings are open, replace the compressor.
	Low water Temperature	-If temperature of water in the water loop is below the set point of the low water temperature cut-out, the safety circuit will be opened and the compressor will not run.
	Low Ambient and No water Flow	-If unit remains in an unconditioned area and the low water temperature cut-out is set to a temperature above that sensed, the compressor will not run just as in the instance of low water temperature.

Complaint	Possible Cause	Correction
Unit off on High Press Cut-Out Control	Defective high Pressure Switch	-Stuck open, does not reset or has defective calibration. A replacement switch is available that attaches to service port. When it is necessary to replace either of the pressure switches or reversing valves, wrap them with a wet cloth and direct the heat away when brazing. Excessive heat can damage them.
	Refrigerant Charge	-The unit is overcharged with refrigerant. Bleed some charge.
	Discharge Pressure too High	-On COOLING cycle[water source]: Lack of or inadequate water flow. Entering water too warm. Scaled or plugged condenser. On COOLING Cycle [air source]: Outdoor section has poor air flow. Coil may be blocked by leaves or other debris. Fan may not operate properly. Fan disconnect

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
		(if installed) may be open. On HEATING cycle: Lack of or inadequate air flow. Entering air too hot. Blower inoperative, clogged filter or coil, restrictions in duct work.
Suction Pressure Too Low	System Conditions	-On COOLING cycle: Lack of or inadequate air flow. If belt drive check belt. Entering air too cold. Blower inoperative, clogged filter or coil, restrictions in duct work. On HEATING cycle: Lack of or inadeqaute water flow or air flow. Entering water or air too cold. Scaled or plugged condenser. When unit has been inoperative for several days, it may be necessary to start unit, return thermostat to a satisfied condition, allow the unit to complete its pumpdown cycle, then return the thermostat to its desired setting.
	Refrigerant Charge	-The unit is overcharged with refrigerant. Bleed off some charge or evacuate and recharge with specified amount of R-22.
	High Pressure Switch	-Check for defective or improperly calibrated high pressure switch.
Unit Off on Low Pressure Cut-out Control	Suction Pressure too low	-On COOLING Cycle: Lack of or inadequate airflow. Entering air too cold. Blower inoperative, clogged filter or coil, restrictions in duct work. -On HEATING cycle: Lack of or inadequate water flow. Entering water too cold. Scaled or plugged condenser.
	Refrigerant Charge	-The unit is low in charge of refrigerant. Locate leaks, repair, evacuate, and recharge with specified

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
		amount of R-22.
	Low Pressure Switch	-Check for defective or improperly calibrated low pressure switch.
Unit Short Cycles	Thermostat	-The differential is set too close in the thermostat. Readjust setting.
		-Move thermostat to a better location for sensing average room temperature.
	Wiring and controls	-Loose connections in the wiring or the control contactors defective.
	Compressor Overload	-Defective compressor overload, check and replace if necessary. If the compressor runs too hot it may be due to the deficient refrigerant charge.
Insufficient Cooling or Heating	Unit undersized	-Recalculate heat gains or losses for spaces to be conditioned. If excessive rectify by adding insulation

Complaint	Possible Cause	Correction
		shading, etc.
	Loss of Conditioned air by leaks	-Check for leak in ductwork or introduction of ambient air through doors and windows.
	Thermostat	-Improperly located thermostat (e.g. near kitchen sensing inaccurately the comfort level in living areas). Relocate.
	Airflow (Indoor)	-Lack of adequate air flow or improper distribution of air. Chec the belt tension or duct sizing. Check the filter, it should be inspected every three months and changed if dirty.
	Airflow (outdoor)	-Airflow across outdoor coil may be restricted by leaves or other accumulated debris.
	Refrigerant Charge	-Low on refrigerant charge causing inefficient operation.
Insufficient cooling or heating	Compressor	-Check for defective compressor. If discharge pressure is too low and suction pressur too high compressor is not pumping properly

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
		Replace Compressor.
	Reversing valve	-Defective reversing valve creating by-pass of refrigerant from discharge to suctionside of compressor. When it is necessary to replace the reversing valve, wrap it with a wet cloth and direct the heat away when brazing. Excessive heat can damage the valve.
	Operating Pressure	-Incorrect operating pressure (See chart)
	Refrigerant System	-Check strainer and tapillary tubes for possible restrictions to flow of refrigerant. The refrigerant system may be contaminated with moisture, non-condensibles and particles. Dehydrate, evacuate and recharge the system.

Complaint	Possible Cause	Correction
	Water	-Lack of sufficient pressure, temperature and/or quantity of water. Possible scaling in condenser clean, and descale.
Noisy Operation	Compressor	-Make sure the compressor is not in direct contact with the base or sides the cabinet. The hold down bolts used for shipping should be loosened so that the compressor is floating free on its isolator mounts. Excessive noise will occur if the compressor has a broken valve or loose discharge tube. Replace the compressor.
	Blower and blower motor	-Blower wheel hitting the casing. Adjust for clearance and alignment. Bent blower, check and repla if damaged. Loose blow motor on shaft. Check and tighten. Defective bearings, check and replace.
	Contactors	-A 'clattering' or 'humming' noise in

Solar Auxiliary Unit (cont'd)

Complaint	Possible Cause	Correction
		the contactor could be due to control voltage less than 18 volts. Check for low supply voltage, low transformer output or extra long runs of therm-stat wires. If the contactor contacts or coil is defective repair or replace.
	Rattles and Vibrations	-Check for loose screws, panels or internal components. Tighten and secure. Copper piping could be hitting the metal surfaces. Carefully readjust by bending slightly.
	Airborne Noises and other sounds	-Undersized duct-work will cause high airflow velocities and noisy operations. Excessive water through the water-cooled heat ex-changer will cause a rattling sound. Throttle back on

Complaint	Possible Cause	Correction
		the water flow ensuring adequate flow for good op-eration but elimina-ting the noise
	Water	-Reduce water pressure to 35 pounds if a Dole water valve is used.
Water Leak	Plugged con-densate drain or machine out of level	-Condensate drains pick up dirt or algae can grow causing the drain outlet to clog and condensate to overflow. Inspect and clean. Check level of the unit and adjust.
	Condensate Trap not installed	-Install proper condensat trap.
Unit Heats Only	Reversing valve does not shift	-The solenoid valve may be deenergized possibly due to mis-wiring at the unit or at the thermostat. The valve may be stuck. The thermostat may be in the heat position.

Space Heating Distribution system

Complaint	Possible Cause	Correction
Uneven Heat dis-tribution in residence	Damper in ducts set incorrectly	-Balance the air dis-tribution ducts to obtain the specified airflow through each.

Space Heating Distribution System (cont'd)

Complaint	Possible Cause	Correction
Solar Auxiliary Unit shuts off	Line restricted by air stoppage in water line.	-Vent air at manual air vent.
		-Clean strainer; drain line and blow out with compressed air.
	Pump Malfunction	-Repair or replace pump.
Inadequate airflow through ducts	Dirty blower filter	-Replace filter
	Faulty Blower	-Repair blower.
	Excessive dust accumulation in ducts	-Remove covers; vacuum ducts.

Control System:

Complaint	Possible Cause	Correction
Not enough heat	Blown fuse	-Replace or reset fuse
Control panel fuses blow repeatedly	Malfunction in one or more components	-Locate and repair fault
One or more system operating modes dysfunction	Failure in control panel	-Check relays; circuits governing affected mode, replace faulty controls

Complaint	Possible Cause	Correction
	Failure of Active Component (pump, solenoid valve, etc.)	-Locate, repair or replace faulty component.

14.0 Periodic Maintenance Schedule

Time Interval	Action
Solar Collection System (attic)	
6 Months	Check the angle of the movable flap and adjust the Solar Altitude Compensator if necessary.
12 Months	Dust the reflective panels. Vacuum the gearmotor ventilation openings to prevent dust from accumulating in the windings. Dust the absorbers. Wash the window of the solar system, at the same time examine it for leaks, broken panes.
5-10 Years	Lubricate the gearmotor of the Solar Altitude Compensator as described in Chapter 6.
Water Circulation and Storage System	
1 Month	Note the storage tank temperature. It should be high after consecutive sunny days. Check the water level in the storage tank. Add makeup water as necessary and investigate any leaks.

Time Interval	Action
6 Months	Clean the strainers upstream of all the pumps in the solar system. Check the pressure in the domestic hot water loop. If it is low, investigate the possibility of a leak.
12 Months	Verify that the automatic air vents and vacuum breakers on the plumbing loops are functioning properly.
2 Years	Test the pH and hardness of the water in the storage tank.
Control System	
1 Month	Examine electric fuel bills for unusually large consumption. This could result from the use of auxiliary resistance heat, indicating a malfunction in either the control system or one of the active components (pump, solenoid valve, air vent) of the solar system.
6 Months	Inspect the contacts and relays in the control panel.
12 Months	Inspect the control panel as described in Chapter 12. Also repeat the "System Check Out", which tests each operating mode

Time Interval	Action
Control System (cont'd)	
	of the heating and cooling system. It is most beneficial to perform this test in the fall of the year before the heating season begins.
Solar Auxiliary Unit	
3 Months	Vacuum or replace the air filter on the blower. If exceptionally dusty conditions prevail, this may have to be done as often as once per month.
6 Months	Inspect the condensate pan and drain. Lubricate the blower motor as described in Chapter 10.
12 Months	Check that the "direct solar coil" of the Solar Auxiliary Unit is receiving adequate air and water flow.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980–740-066/165 REGION NO.4